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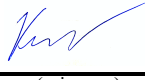
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ABSTRACT

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SIMULATION, VIRTUAL REALITY, VIRTUAL REALITY MODELING LANGUAGE, VIRTUAL SIMULATION

Virtual reality and system simulation are two different and internally related conceptions. The internal relation forms their intersection. Virtual simulation based on the intersection has new characteristics and highlights. It combines the strongpoint of virtual reality and system simulation. So it has become a hot research field and has broad and bright application perspectives. How to apply virtual reality technology to system simulation has been studied thoroughly in this paper. The applicability and limitation of applying virtual reality to system simulation has been analyzed. And graphic modeling technology has been proposed as the medium of this application. The theory foundation and key technology of combining virtual reality technology and graphic modeling technology and applying them to system simulation has been discussed in this paper. The developed system has been applied to process industry system simulation. The study and development of the system is based on the Graphic - Modeling System for Process Dynamic Analysis, which was developed by the author. Based on this system, virtual simulation scene system based on VRML has been implemented. In this paper, the architecture and function modules are introduced in detail, and the difficulties and solutions in the process of developing the systems are also been discussed thoroughly.

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INTRODUCTION

Virtual reality technology is an emerging field that deserves further investigation. To further develop virtual reality technology, its wide range of applications must be highly valued. Although virtual reality technology has already begun to be applied in the field of system simulation, there are few studies on its application in process industrial system simulation. This project aims to conduct in-depth research on the application of virtual reality technology in system simulation, especially in process industrial system simulation.

The establishment of a people-centered and harmonious human-machine environment is one of the key factors in developing simulation systems, and virtual reality technology can serve as a useful tool for displaying simulation models and human-machine interactions in simulation environments. However, its foundation is the establishment of simulation models. Graphics modeling technology is currently a research focus in the simulation modeling field and is one of the core technologies of visualization simulation. The main focus of this project is to study the applicability and limitations of virtual reality technology in system simulation, further identify the mechanism and approach of combining virtual reality technology with graphics modeling technology, and finally propose and implement a feasible design scheme for a graphics modeling virtual simulation system.

The specific research and development work of this project will be combined with a "graphics modeling system for process dynamic research" to study how to apply graphics technology to the development of simulation modeling systems, and solve the difficult problems involved in circuit connection topology analysis, light and shadow effect rendering, and multi-level nested icons in the graphics modeling process. On the basis of this graphics modeling system, virtual reality technology will be organically integrated to study the presentation of virtual simulation scenes and the dynamic and interactive nature of virtual simulation scenes.

1 ANALYSIS OF THE APPLICATION OF GRAPHIC TECHNOLOGY IN SIMULATION

1.1 The Development of Simulation Modelling

The establishment of simulation models [2-10] is a very complex and time-consuming process, and research on modeling technology [8, 11, 13] has always been a focus of system simulation personnel. Traditional modeling methods are divided into two categories: program modeling and interactive command modeling. The modeling operations are complex, the internal connection relationships of the model are not intuitive, the readability is poor, and analysis and maintenance are inconvenient.

With the updating of computer technology, simulation modeling methods have gone through several stages, from direct programming, simulation language modeling, interactive command modeling to graphic modeling. Although the methods and forms of modeling have undergone significant changes, in essence, modeling methods are still mainly divided into two categories: program modeling and modular modeling.

Program modeling is the direct use of programming languages or digital simulation languages to compile simulation model programs. Its advantages are compact model structure and fast operation speed. However, program modeling requires higher requirements for modelers, not only requiring rich professional knowledge and mathematical knowledge but also requiring multiple skills in modeling, simulation, and computer applications. Since the generated model exists directly in the form of a program, it is not convenient for analysis and maintenance. The model needs to be compiled and linked before it can run, and it is also inconvenient to modify and debug.

Modular modeling is a traditional and effective modeling method. It is based on the general steps of dynamic large system modeling, decomposes the large system into subsystems composed of several basic units according to level, hierarchy, and function, and then uses mathematical and physical analysis methods to establish mathematical models of these basic units to form an algorithm library. Each algorithm corresponds to a class of basic units. Finally, according to the physical process of the actual system,

these algorithms are used to construct the simulation model. Modular modeling has the advantage that once a model is established for a typical system or device, system changes can be achieved simply by modifying its parameters, and the established model can also be applied to other systems with similar mathematical and physical structures. Modular modeling can be accomplished by using interactive command methods to establish mathematical modules for the simulated object. Typically, the modeling personnel set the inputs, outputs, and coefficients of each module in a table and fill in the module variable names in the corresponding positions to establish the connection between algorithms and complete the model. Compared to program modeling, this modeling method has made great progress in reducing the requirements for modeling personnel. The built modules can directly participate in operation without the need for compilation or linkage. However, an inevitable disadvantage is that the modeling process is relatively complex and requires a lot of keyboard operations. The connection between modules is not intuitive, and modeling personnel are required to remember a large amount of relevant information, which inevitably brings inconvenience to the analysis and maintenance of the model.

The text command interaction method for building models is cumbersome and not easy to understand or remember, but using graphical representations to depict the model can intuitively reflect various model information, model characteristics, and the connection and transmission relationships between signals, making it easier for analysis and maintenance. Therefore, the visualization of the modeling process and how to construct a graphical integrated modeling environment have become a research hotspot.

1.2 Graphic Modelling

Modern simulation objects are complex large systems with interconnected and interdependent parts. The relationships are complex and intertwined. Therefore, it is particularly important to express the logical relationships between the various parts of

the system in a scientific and intuitive manner. In order to improve the modeling environment, many simulation research institutions at home and abroad have conducted research on various graphic modeling techniques. Since the environment in which humans live is itself a series of pictures, expressing information in graphic form has the advantages of being intuitive, concise, and easy to understand. Applying graphic technology in simulation can include much information that is difficult to express in language, making communication easier, and reducing the level of user operating skills required [22, 23].

The general idea of graphic modeling is to use icons to represent physical devices in reality and establish corresponding relationships between the icons and the algorithms in the algorithm library. During modeling, the icons are called in the front-end graphic environment using icon calling methods to complete the calling of the algorithms in the back-end algorithm library. Connections are made between any two related icons to represent the direction of logistics, thereby forming the framework of process flow simulation.

Using graphic modeling technology [13-15], the complex logical relationships between objects in the system can be described visually, and the modeling process can be simplified. This provides a convenient way to obtain and express information visualization in simulation modeling. Therefore, how to establish a visual operation platform that enables users to easily and intuitively construct the entire system simulation model has become a research focus.

1.3 Analysis of 3D modeling methods

In recent years, the convergence of 3D modeling and virtual reality (VR) technologies has marked a transformative shift in the way we interact with computer systems. The fusion of these two domains opens up unprecedented possibilities for immersive experiences, impacting fields ranging from gaming and simulation to

education and professional training. As VR systems become increasingly integral to our digital landscape, the demand for sophisticated 3D models tailored for these environments has surged.

This background sets the stage for a comprehensive exploration of the methods employed in the development of 3D models, particularly those optimized for virtual reality applications. Understanding the historical context, technological advancements, and the driving forces behind this intersection is essential to appreciate the complexities involved in crafting virtual experiences that seamlessly blend with the real world.

The primary objective of this analysis is to scrutinize the diverse methods utilized in the creation of 3D models with a specific emphasis on their compatibility and efficacy within virtual reality computer systems. By delving into the intricacies of various modeling techniques, this study aims to provide a nuanced understanding of their strengths, weaknesses, and applications in virtual reality environments.

Through an in-depth exploration of procedural modeling, polygonal modeling, parametric modeling, sculpting, and other pertinent techniques, we seek to unravel the intricacies that define each method. Furthermore, this analysis endeavors to elucidate the implications of these modeling approaches on user experience, technical implementation, and overall performance within the dynamic realm of virtual reality.

As we navigate through this exploration, the intent is not only to dissect existing methods but also to identify emerging trends and potential innovations on the horizon. Ultimately, this analysis strives to contribute valuable insights to the ongoing discourse on the symbiotic relationship between 3D modeling and virtual reality, fostering a deeper comprehension of the tools that shape the immersive digital landscapes of tomorrow.

Simulation modeling involves the development and examination of a digital representation of a tangible model to anticipate its real-world functionality. This method aids designers and engineers in comprehending potential failure scenarios, determining the specific conditions under which a component might malfunction, and assessing the various stresses it can endure. Additionally, simulation modeling plays a crucial role in

forecasting fluid dynamics and heat transfer patterns, providing insights into how a system may behave under simulated working conditions using specialized software.

In the realm of 3D computer graphics, the process of 3D modeling entails creating a mathematical, coordinate-based depiction of an object's surface—whether animate or inanimate—in three dimensions. This is achieved through specialized software, manipulating edges, vertices, and polygons within a simulated 3D space.

Three-dimensional (3D) models serve as representations of physical entities, employing a set of points in 3D space connected by geometric elements like triangles, lines, and curved surfaces. These models, comprising data such as points and related information, can be crafted manually, generated algorithmically (via procedural modeling), or produced through scanning methods. Additionally, the surfaces of these models can be further specified through the application of texture mapping.

The term given to the end product is a 3D model, while individuals engaged in working with 3D models may be referred to as either 3D artists or 3D modelers.

The representation of a 3D model can also be translated into a two-dimensional image through a process known as 3D rendering, or it can be incorporated into a computer simulation illustrating physical phenomena.

Creation of 3D models can occur through automated or manual processes. The manual method of preparing geometric data for 3D computer graphics closely resembles techniques found in plastic arts, such as sculpting. Additionally, the physical manifestation of a 3D model is possible through 3D printing devices, constructing the model in 2D layers with three-dimensional material, one layer at a time. It's important to note that without a 3D model, the production of a 3D print is not feasible.

Within the realm of 3D computer graphics, specialized software known as 3D modeling software is utilized to generate these models. Programs falling under this category, such as SketchUp, are commonly referred to as modeling applications.

While 3D models are currently prevalent in various fields, including 3D graphics and computer-aided design (CAD), their origin predates the widespread adoption of 3D graphics on personal computers.

In earlier times, computer games often employed pre-rendered images of 3D models as sprites before computers had the capability to render them in real-time. This approach allowed designers to examine the model from different perspectives and views, aiding in the evaluation of whether the object was created in alignment with their original vision. This visualization method assists designers or companies in identifying necessary changes or improvements to the product.

Most 3D models can be categorized into two main types:

- Solid Models: These models define the volume of the object they represent, such as a rock. Primarily utilized in engineering and medical simulations, solid models are often constructed using constructive solid geometry;
- Shell or Boundary Models: These models represent the surface or boundary of the object rather than its volume, akin to an infinitesimally thin eggshell. Shell models are commonly employed in visual representations for games and film.

Both solid and shell modeling techniques can produce objects with identical functionality. The distinctions between them generally lie in their creation and editing processes, conventions of use across different fields, and variations in types of approximations made between the model and reality.

For a shell model to be meaningful as a real object, it must be manifold, meaning it has no holes or cracks in the shell. In the case of a cube's shell model, the bottom and top surfaces must have uniform thickness without any holes or cracks in the first and last layer printed. The most prevalent representation is through polygonal meshes, with subdivision surfaces and, to a lesser extent, level sets also being used. Level sets are particularly useful for deforming surfaces that undergo numerous topological changes, such as fluids.

The process of transforming object representations, like converting the middle point coordinate of a sphere and a point on its circumference into a polygon representation of a sphere, is termed tessellation. This step is integral in polygon-based rendering, where objects transition from abstract representations ("primitives") like spheres and cones to meshes, consisting of interconnected triangles. Triangular meshes are popular due to their ease of rasterization, as the surface described by each triangle is

planar, ensuring a convex projection. It's worth noting that polygon representations are not universally employed in all rendering techniques, and in such cases, the tessellation step is excluded in the transition from abstract representation to the rendered scene.

1.3.1 Overview of 3D Modeling

3D modeling stands as a pivotal discipline within the realm of computer graphics, enabling the creation of three-dimensional representations of objects, scenes, and environments. At its core, 3D modeling involves the use of mathematical representations to define the shape, appearance, and properties of virtual entities. This section will provide a comprehensive definition of 3D modeling, elucidating its fundamental principles and exploring the conceptual framework that underpins this transformative discipline.

The conceptual framework encompasses various methodologies, algorithms, and mathematical constructs that form the basis of 3D modeling. From geometric primitives to complex surface representations, understanding the core concepts is crucial for grasping the intricacies of different modeling techniques. This section will delve into the foundational elements, offering readers a solid grounding in the theoretical aspects that govern 3D modeling processes.

The evolution of 3D modeling within computer systems traces a captivating journey from its nascent stages to the sophisticated methodologies employed today. This subsection aims to provide a historical overview, highlighting key milestones and technological advancements that have shaped the landscape of 3D modeling.

Beginning with the earliest wireframe models and rudimentary rendering techniques, we will explore the gradual integration of 3D modeling into computer systems. The advent of polygonal modeling, parametric modeling, and advancements in computational power have played pivotal roles in expanding the capabilities of 3D modeling applications.

The evolution is not solely technological; it is also influenced by the growing diversity of applications, from entertainment and gaming to scientific simulations and architectural visualization. By tracing this evolution, we gain valuable insights into the challenges overcome, the breakthroughs achieved, and the collaborative efforts across

interdisciplinary fields that have propelled 3D modeling into a central role within the broader landscape of computer science and digital creativity.

1.3.2 Procedural Modeling

Procedural modeling is a technique in 3D computer graphics that involves the use of algorithms and rules to generate three-dimensional models. Instead of manually crafting each element of a model, procedural modeling relies on systematic instructions to create complex and intricate structures. This subsection will delve into the essence of procedural modeling, exploring its defining characteristics and the underlying principles that differentiate it from other modeling methods.

Procedural models are constructed through the application of rules and parameters, allowing for the generation of diverse and realistic shapes. These rules can range from mathematical functions defining geometry to algorithms governing texture and detail. The dynamic nature of procedural modeling enables the creation of highly detailed and scalable models, making it a powerful approach for certain applications.

Procedural modeling finds applications across various domains, notably in the creation of natural environments, landscapes, and intricate geometric structures. In the gaming industry, procedural modeling is often employed to generate expansive terrains, realistic ecosystems, and complex architectural elements. Beyond entertainment, it is utilized in simulations, where dynamic and adaptable models are essential for training scenarios.

The scalability of procedural models makes them particularly valuable in virtual reality environments, where real-time rendering and adaptability to user interactions are crucial. From procedural generation of cities in virtual worlds to the creation of diverse ecosystems, the applications of procedural modeling are expansive and continually evolving.

Procedural modeling offers several advantages, including efficiency in creating vast and detailed environments. The ability to tweak parameters allows for a high degree of flexibility, enabling artists and developers to iterate rapidly. Moreover, procedural models can be easily adapted to different levels of detail, making them suitable for a range of applications.

However, procedural modeling is not without its limitations. Fine-tuning specific details manually may be challenging, as the model's complexity often arises from the automated application of rules. Striking a balance between control and automation is a perpetual challenge. Additionally, achieving highly specific, stylized, or intricate designs might require supplemental manual intervention.

Understanding these advantages and limitations is crucial for informed decision-making when choosing procedural modeling in a 3D modeling workflow. This subsection will comprehensively explore the nuanced aspects that define procedural modeling within the broader classification of 3D modeling methods.

1.3.3 Polygonal Modeling

Polygonal modeling is a widely employed 3D modeling technique that represents objects and surfaces using interconnected polygons. Typically, these polygons are triangles or quadrilaterals, forming a mesh that approximates the surface of the modeled object. This subsection aims to define the fundamentals of polygonal modeling and delineate its key characteristics.

The essence of polygonal modeling lies in the creation of a mesh composed of vertices, edges, and faces. By manipulating these elements, 3D artists can sculpt and define the shape of a model. The simplicity and efficiency of representing surfaces with polygons make this method particularly suitable for a broad range of applications, from character modeling to architectural design.

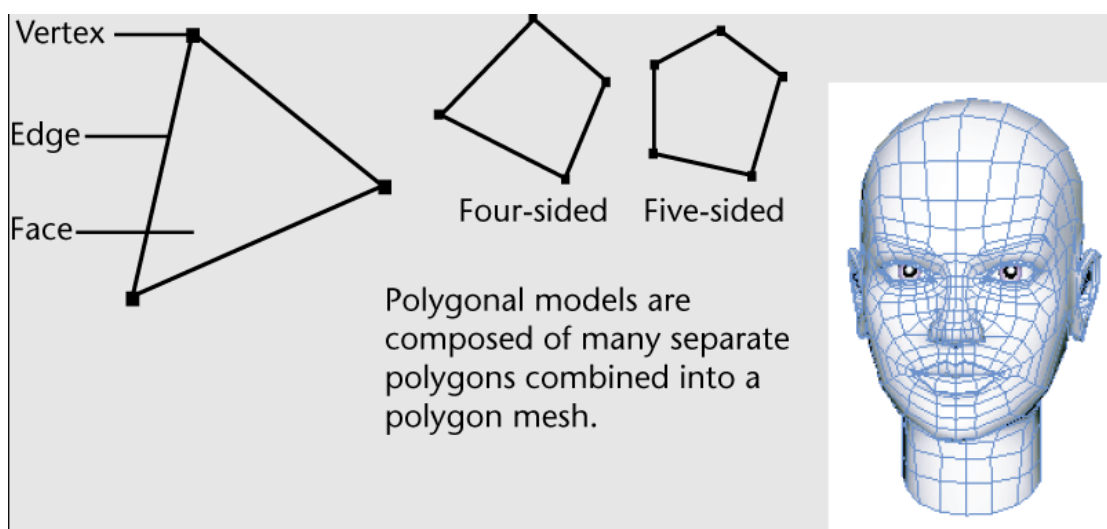


Figure 1.1 – Polygonal modeling

Polygonal modeling finds extensive applications in various industries, notably in the creation of characters and assets for video games, animations, and movies. Its ability to efficiently represent complex shapes and surfaces has made it a staple in the entertainment industry. Additionally, polygonal modeling is frequently employed in architectural visualization, where it facilitates the creation of detailed and realistic building structures.

In virtual reality environments, where real-time rendering is crucial, polygonal models are preferred due to their computational efficiency. The versatility of polygonal modeling allows for the creation of both organic and inorganic forms, making it suitable for a diverse array of virtual reality experiences.

Polygonal modeling offers several advantages, including a straightforward representation of surfaces, ease of manipulation, and compatibility with real-time rendering engines. The structured nature of polygonal meshes facilitates smooth animations and deformation of models.

However, polygonal modeling has its limitations. Achieving highly detailed and curved surfaces may require a substantial increase in polygon count, potentially impacting performance. Additionally, realistic representation of organic forms might demand intricate modeling techniques, sometimes necessitating the use of other methods like sculpting.

This subsection will explore the nuanced aspects of polygonal modeling, shedding light on the reasons behind its widespread adoption and the considerations that artists and developers must weigh when choosing this method in their 3D modeling workflows.

1.3.4 Parametric Modeling

Parametric modeling is a technique within 3D computer graphics that involves defining a model's shape using parameters and mathematical equations. This subsection seeks to elucidate the core concepts of parametric modeling and outline its distinctive characteristics.

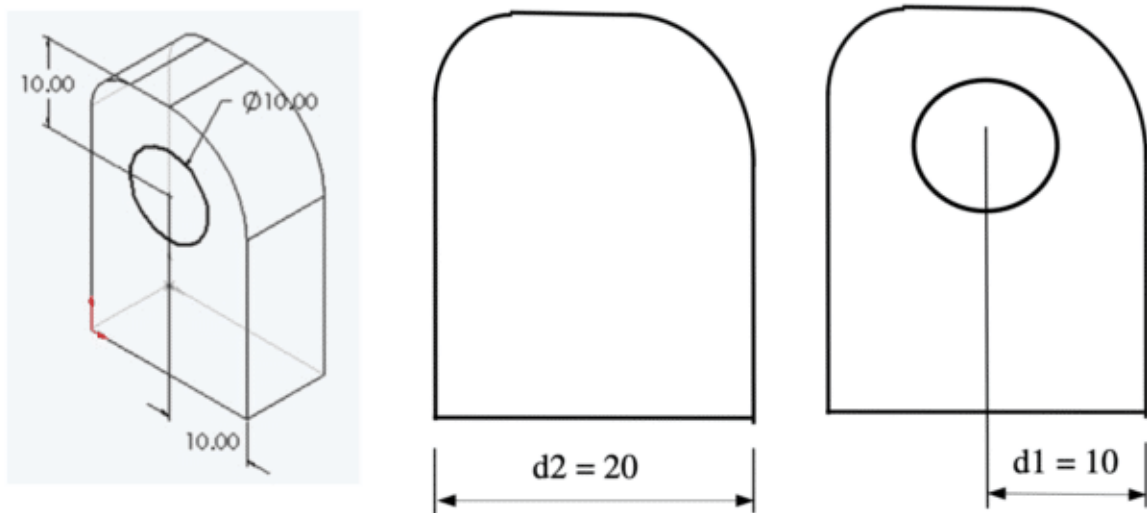


Figure 1.2 – Parametric modeling

At its foundation, parametric modeling allows for the creation of models through the adjustment of predefined parameters, such as dimensions, angles, or other geometric attributes. This method introduces a level of procedural control, enabling designers to modify the model systematically by altering these parameters. The mathematical relationships between elements contribute to the precision and predictability of parametric models.

Parametric modeling finds applications across diverse industries, particularly in product design, architecture, and engineering. Its systematic approach allows designers to create variations of a model efficiently, making it an invaluable tool for prototyping and iterative design processes. In architecture, parametric modeling is often used to generate complex structures that respond dynamically to environmental factors.

Within virtual reality systems, where interactive and dynamic models are crucial, parametric modeling provides a foundation for adaptive and customizable 3D content. The ability to modify models on-the-fly based on user input or environmental conditions enhances the immersive qualities of virtual reality experiences.

Parametric modeling offers notable advantages, including rapid design iteration, precise control over geometric attributes, and the ability to create families of related models through parameter adjustments. This method is particularly advantageous in scenarios where systematic variations of a design are required.

However, parametric modeling has its limitations. Achieving highly organic or irregular shapes may pose challenges, as the mathematical relationships may struggle to accurately represent such forms. Additionally, the learning curve for mastering parametric modeling software can be steep, requiring a solid understanding of both design principles and mathematical concepts.

This subsection aims to provide a comprehensive understanding of parametric modeling, shedding light on its applications, strengths, and considerations for practitioners in the realm of 3D computer graphics and virtual reality development.

1.3.5 Sculpting

Sculpting in the context of 3D modeling involves a more organic and intuitive approach to shape creation. Artists use digital sculpting tools to directly manipulate a virtual clay-like material, allowing for the creation of intricate and detailed models. This subsection aims to define the principles of sculpting in 3D modeling and highlight its key characteristics.



Figure 1.3 – Digital sculpting

Digital sculpting relies on the simulation of traditional sculpting techniques in a digital environment. Artists utilize brushes and tools to push, pull, and shape the virtual material in a manner analogous to sculpting with physical clay. This approach fosters a

high level of artistic expression and creativity, enabling the crafting of highly detailed and visually compelling 3D models.

Sculpting has found widespread applications in the creation of characters for animation, video games, and movies. The organic and expressive nature of sculpting tools makes it particularly suitable for generating lifelike and emotionally resonant characters. Additionally, sculpting is often employed in the creation of natural elements such as terrain, foliage, and organic structures.

In virtual reality, sculpting tools offer an immersive way for artists to shape the virtual world directly. This hands-on approach enhances the sense of presence and allows for real-time adjustments, making sculpting an invaluable method for VR content creation. Beyond entertainment, sculpting is utilized in fields such as product design and medical visualization.

Sculpting provides several advantages, including a natural and intuitive workflow, the ability to create highly detailed and intricate designs, and a direct connection between the artist's gestures and the model's form. The tactile nature of sculpting tools allows for a more immersive and artistic experience.

However, sculpting also has its limitations. Achieving precise geometric shapes may be challenging compared to more parametric or procedural approaches. Additionally, the reliance on high-resolution meshes can pose challenges for real-time performance in certain applications.

This subsection aims to explore the unique characteristics of sculpting in the realm of 3D modeling, emphasizing its applications, strengths, and considerations for practitioners in various creative and professional fields.

1.3.6 Virtual Reality-specific Modeling Techniques

Virtual Reality (VR) presents a unique set of challenges and opportunities for 3D modeling, necessitating specialized techniques tailored to the immersive nature of virtual environments. This section provides an overview of modeling methods specifically designed or adapted for virtual reality applications. Understanding these techniques is crucial for creating content that optimally aligns with the demands of VR experiences.

Virtual reality-specific modeling techniques go beyond traditional approaches to address the dynamic and interactive nature of VR environments. Whether for game development, architectural visualization, or training simulations, these techniques aim to enhance user engagement and presence within the virtual space.

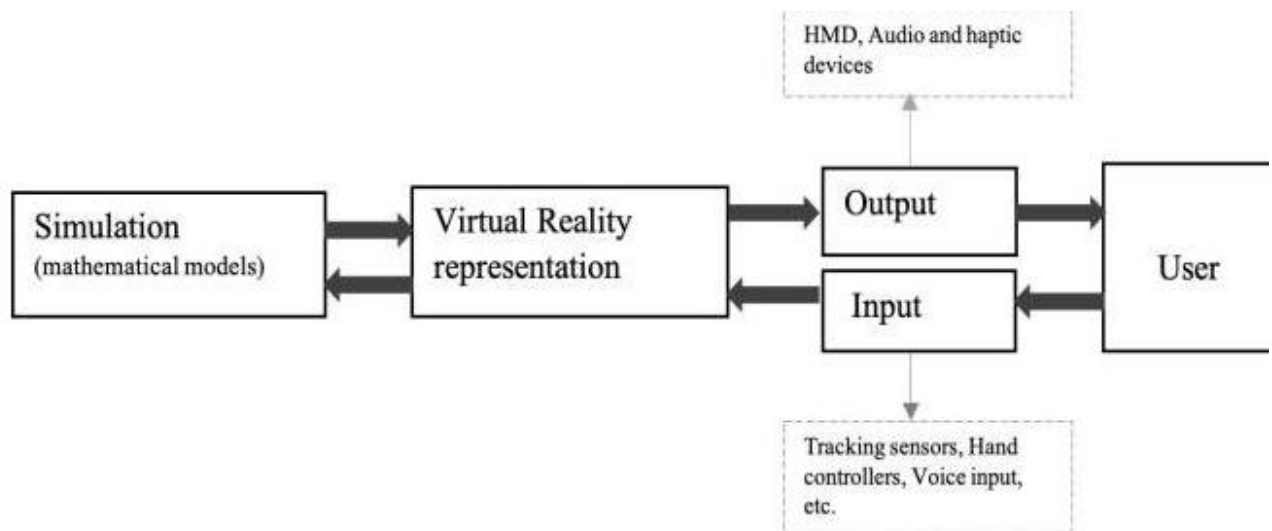


Figure 1.4 – Generic model of virtual Reality simulation

Integration with virtual reality systems involves the seamless incorporation of 3D models into the VR environment, considering factors such as real-time rendering, user interaction, and spatial awareness. This subsection explores how virtual reality-specific modeling techniques are integrated into VR systems to enhance the overall immersive experience.

Specialized tools and workflows are often employed to optimize 3D models for VR, considering factors like performance, scale, and user interaction. Techniques such as level-of-detail adjustments, real-time shading, and spatial audio integration contribute to a more immersive and responsive virtual environment.

The integration of 3D modeling with virtual reality introduces a set of challenges and opportunities. Challenges may include maintaining performance standards, ensuring comfort in VR experiences, and addressing issues related to scale and proportions. Opportunities arise in the form of novel interaction possibilities, user-driven content creation within VR, and the potential for more realistic and immersive simulations.

This section delves into the complexities of adapting 3D modeling techniques for virtual reality, discussing challenges faced by developers and opportunities for innovation. By understanding the intricacies of this integration, practitioners can make informed decisions when creating content for the rapidly evolving landscape of virtual reality.

1.3.7 Comparative Analysis

In this section, we undertake a technical analysis of various 3D modeling methods, including procedural modeling, polygonal modeling, parametric modeling, sculpting, and virtual reality-specific techniques. Key technical aspects to be scrutinized include the precision and complexity of model creation, ease of manipulation, and adaptability to different design requirements. Understanding the technical intricacies of each method is essential for selecting the most suitable approach based on project objectives and constraints.

User experience plays a pivotal role in the effectiveness of 3D modeling methods, particularly in the context of user interactions with virtual environments. This subsection evaluates the user experience aspects of each modeling method, considering factors such as ease of use, artistic freedom, and the intuitive nature of the design process. Examining how artists and designers engage with these methods sheds light on their practicality and efficiency in real-world scenarios.

The performance of 3D modeling methods within virtual reality environments is a critical consideration, impacting the fluidity and responsiveness of VR experiences. This section explores how procedural modeling, polygonal modeling, parametric modeling, sculpting, and virtual reality-specific techniques fare in terms of real-time rendering, adaptability to VR hardware constraints, and responsiveness to user interactions. Evaluating the performance of each method within the unique demands of virtual reality is crucial for optimizing immersive experiences.

By undertaking a comparative analysis of these technical aspects, user experience, and performance in virtual reality, this section aims to provide a comprehensive understanding of the strengths and limitations of each 3D modeling method. Such insights enable informed decision-making in selecting the most

appropriate method for specific project requirements and contribute to the ongoing discourse on the evolution of 3D modeling practices.

1.3.8 Future Trends in 3D Modeling for Virtual Reality

As the field of 3D modeling continues to evolve, this section explores emerging technologies and techniques that are shaping the future of 3D modeling for virtual reality. From advancements in machine learning and artificial intelligence aiding in automated content generation to the integration of haptic feedback for more immersive sculpting experiences, this subsection delves into cutting-edge technologies influencing the trajectory of 3D modeling.

Additionally, the exploration of emerging techniques such as generative adversarial networks (GANs) for content creation, real-time collaborative modeling in virtual environments, and advancements in photogrammetry contributes to a forward-looking perspective on the tools and methods that will redefine the landscape of 3D modeling.

Looking ahead, this subsection anticipates future developments and innovations within the realm of 3D modeling for virtual reality. The discussion encompasses areas such as improved realism in material representation, enhanced physics simulations for dynamic virtual environments, and the evolution of parametric modeling techniques to offer even more intuitive controls.

Moreover, the integration of extended reality (XR) technologies, including augmented reality (AR) and mixed reality (MR), is likely to introduce novel possibilities for 3D modeling. Anticipated innovations may also address challenges related to content optimization for diverse VR hardware platforms, further streamlining the development process.

The future trends in 3D modeling have direct implications for virtual reality systems. This subsection explores how the anticipated developments and emerging technologies will impact the design, functionality, and user experience of VR systems. It addresses considerations such as increased hardware requirements, improved content interoperability, and the potential for more intuitive user interfaces within virtual reality environments.

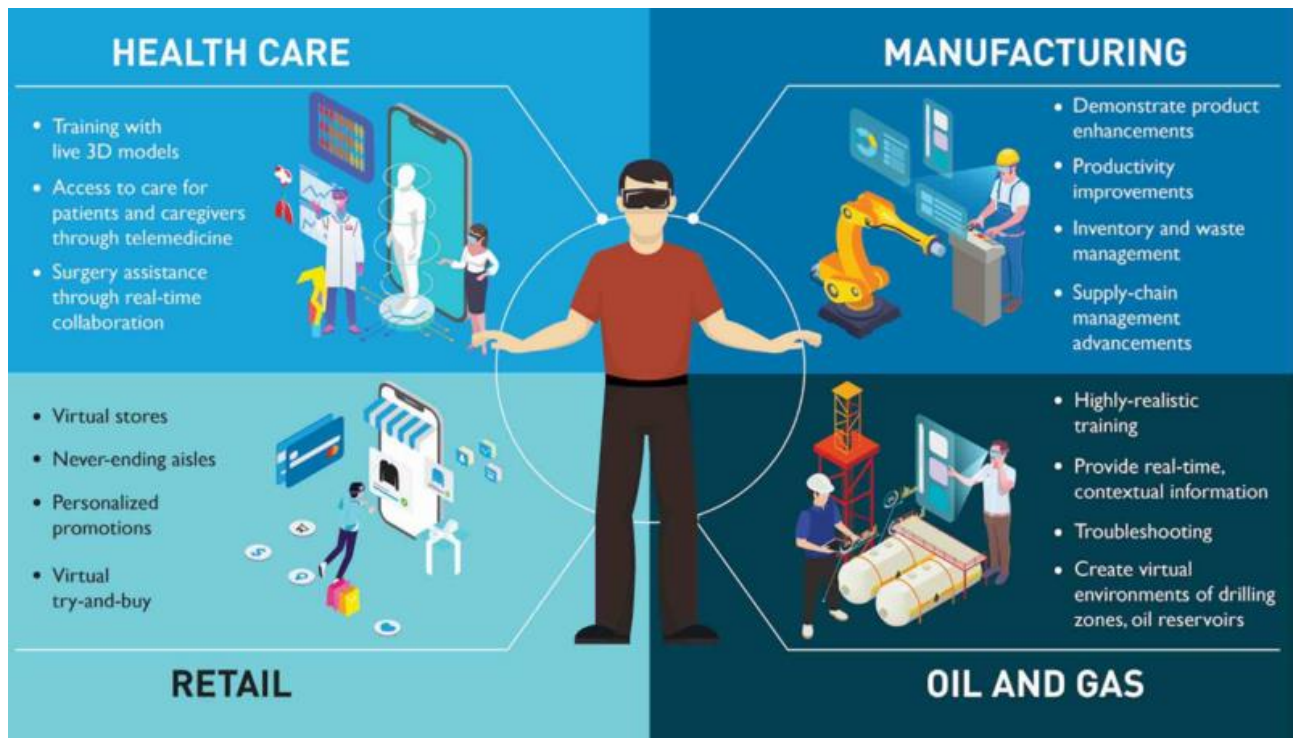


Figure 1.5 – The Future Looks for AR/VR/MR

Additionally, the section assesses the implications of these trends on the broader adoption of virtual reality, including potential shifts in content creation pipelines, collaborative design processes, and the democratization of 3D modeling tools. Understanding these implications is crucial for developers, designers, and industry stakeholders seeking to stay at the forefront of the dynamic intersection between 3D modeling and virtual reality.

By examining emerging technologies, anticipating developments, and assessing implications, this section provides a forward-looking perspective that guides the conversation on the future trajectory of 3D modeling in the context of virtual reality.

1.4 Analysis of 3D modeling tools

1.4.1 Categorization of 3D Modeling Software

In this section, we provide a comprehensive overview of the diverse landscape of 3D modeling tools, categorizing them based on their characteristics, accessibility, and applications. Understanding the categories of 3D modeling software is fundamental for practitioners seeking the most suitable tools for their virtual reality content development.

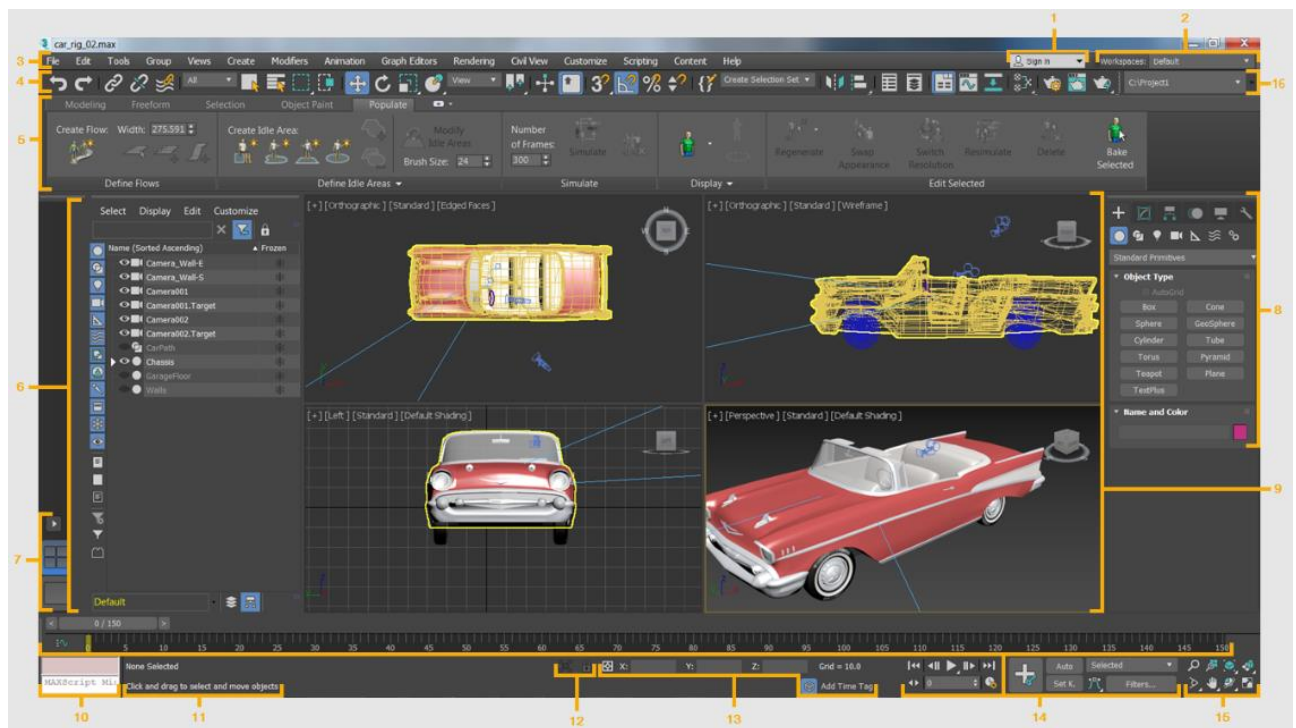


Figure 1.6 – Autodesk 3ds Max interface

Industry-standard Tools. Industry-standard 3D modeling tools have established themselves as benchmarks in the field, widely adopted for their robust features, extensive capabilities, and compatibility with various industries.

This subsection will delve into prominent tools such as Autodesk Maya, 3ds Max, Keyshot and Cinema 4D, highlighting their role in professional workflows and their significance in the development of virtual reality content.

Open-source and Free Software. Open-source and free 3D modeling software play a crucial role in democratizing content creation by providing accessible tools to a broad user base. Blender, SketchUp, and Wings 3D are notable examples in this category. This subsection explores the features and benefits of these tools, addressing their potential for collaboration, community-driven development, and their relevance in virtual reality content creation.

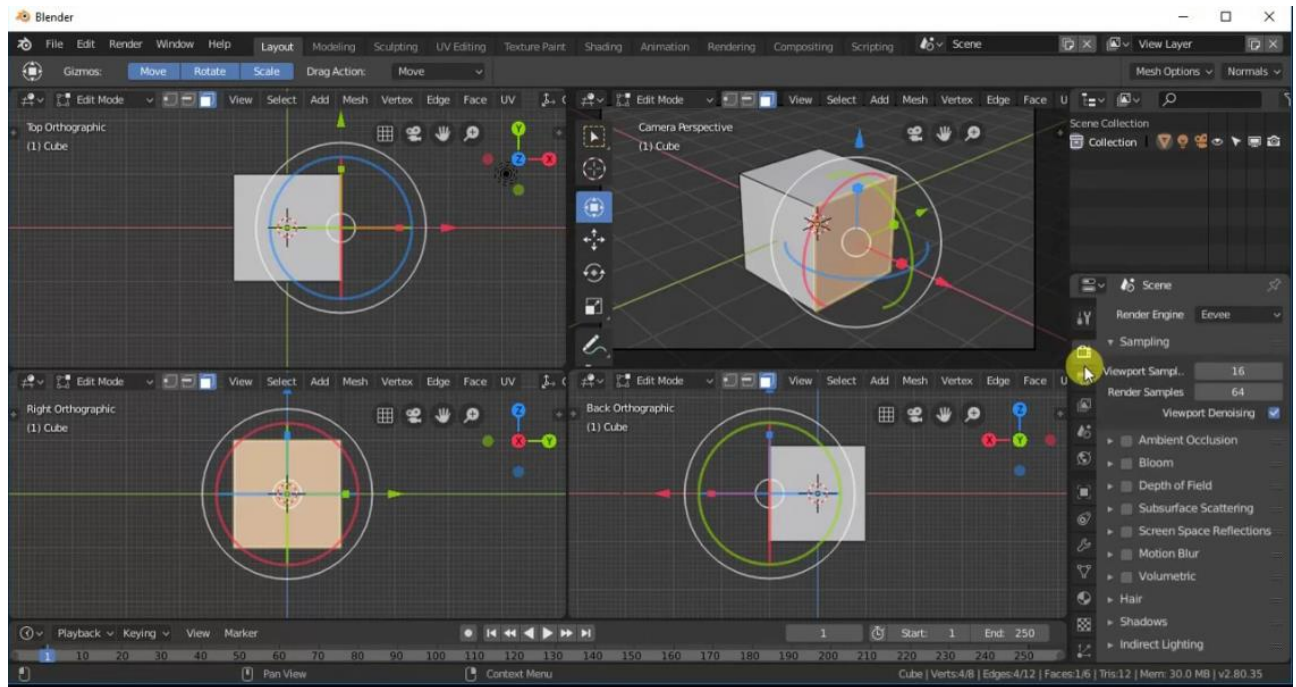


Figure 1.7 – Blender interface

Specialized Tools for Virtual Reality. As the demand for VR content grows, specialized 3D modeling tools designed explicitly for virtual reality environments have emerged. Gravity Sketch, Oculus Medium, and MasterpieceVR are examples of such tools. This part of the section evaluates their unique features, VR-centric interfaces, and their role in enhancing the creative process for virtual reality experiences.



Figure 1.8 – Gravity Sketch interface

By categorizing 3D modeling tools into industry-standard, open-source, and specialized categories, this section provides a foundational understanding of the diverse toolsets available to virtual reality content developers. The subsequent analysis will then explore these categories in greater detail, addressing their respective strengths, weaknesses, and implications for virtual reality modeling workflows.

1.4.2 Comparative Evaluation of 3D Modeling Software

Technical Features. Understanding the technical capabilities of 3D modeling tools is crucial for selecting the right software for virtual reality content creation. This section conducts a comparative evaluation of technical features, focusing on key aspects such as modeling capabilities, rendering engines, and animation/rigging tools.

Modeling Capabilities. This subsection delves into the modeling capabilities of various tools, assessing their ability to create diverse and complex 3D models. Specific features to be analyzed include:

- **Geometry Creation Tools:** Examining the range and flexibility of tools available for creating basic geometric shapes and intricate details;
- **Sculpting and Deformation Tools:** Evaluating the ability to sculpt organic shapes and deform models with precision;
- **Parametric and Procedural Modeling:** Analyzing the support for parametric and procedural techniques in shaping 3D assets.

Rendering Engines. Rendering engines play a pivotal role in visualizing 3D models realistically. This subsection focuses on the rendering capabilities of different tools, considering factors such as:

- Real-time Rendering: Assessing the ability of tools to provide real-time feedback on changes made to the model;
- Rendering Quality: Evaluating the quality of final renders in terms of lighting, shadows, and material representation;
- Integration with External Renderers: Exploring the compatibility of tools with external rendering engines for advanced visual effects.

Animation and Rigging Tools. For tools to be effective in virtual reality content creation, robust animation and rigging tools are essential. This subsection evaluates the animation and rigging capabilities of various tools, including:

- Keyframing and Motion Paths: Analyzing the ease of setting keyframes and creating motion paths for animations;
- Character Rigging: Assessing the tools available for rigging characters, including bone systems and skinning options;
- Physics-based Animation: Exploring support for physics simulations in animations, enhancing realism in movement.

By conducting a detailed analysis of these technical features, virtual reality content developers can make informed decisions based on their specific project requirements and preferences. The subsequent sections will further explore the user interface, compatibility with virtual reality systems, and case studies to provide a holistic understanding of each tool's capabilities.

User Interface and Experience. Understanding the user interface and experience of 3D modeling tools is paramount for efficient and enjoyable virtual reality content creation. This section conducts a comparative evaluation focusing on key aspects such as accessibility, workflow efficiency, and collaboration/version control features.

Accessibility and Learning Curve. This subsection explores how easily users can navigate and interact with the interface of each 3D modeling tool. Key considerations include:

- User-Friendly Interface: Evaluating the intuitiveness of menus, toolbars, and navigation controls for ease of use;
- Learning Resources: Assessing the availability and effectiveness of tutorials, documentation, and community support;
- Accessibility Features: Exploring tools' adaptability for users with varying levels of expertise, including beginners and advanced users.

Workflow Efficiency. Efficient workflows are crucial for productivity in virtual reality content development. This subsection delves into the efficiency of workflows, considering:

- Integration of Tools: Analyzing how seamlessly different tools within the software are integrated for a streamlined workflow;
- Customization Options: Evaluating the degree to which users can customize the interface and workflows to suit their preferences;
- Asset Management: Assessing features related to the organization, import, and export of assets for efficient project management.

Collaboration and Version Control. In collaborative virtual reality projects, effective collaboration and version control are vital. This subsection examines:

- Collaborative Features: Assessing tools that facilitate real-time collaboration among multiple users on the same project;
- Version Control Systems: Exploring the availability and functionality of version control systems for tracking changes and managing project history;
- Communication Tools: Evaluating the presence of communication features within the software to enhance collaboration among team members.

By thoroughly analyzing the user interface and experience, this section aims to provide insights into how each 3D modeling tool accommodates user needs, fosters efficient workflows, and supports collaborative efforts in the context of virtual reality content development. These insights will contribute to informed decisions regarding tool selection for specific project requirements and team dynamics.

Compatibility with Virtual Reality Systems. Ensuring seamless integration with virtual reality systems is critical for an effective 3D modeling workflow tailored for

immersive experiences. This section conducts a comparative analysis of 3D modeling tools, focusing on their compatibility with virtual reality systems.

Support for VR Hardware. This subsection assesses the level of support each 3D modeling tool offers for various virtual reality hardware devices. Key considerations include:

- **Headset Compatibility:** Evaluating support for popular VR headsets such as Oculus Rift, HTC Vive, and others;
- **Motion Controller Integration:** Analyzing how well tools integrate with motion controllers for hands-on interaction;
- **Room-Scale VR Support:** Exploring tools' compatibility with room-scale VR setups for a more immersive modeling experience.

Real-time Rendering Capabilities. Real-time rendering is crucial for immediate feedback and iteration in virtual reality content creation. This subsection examines the real-time rendering capabilities of each tool, considering:

- **Frame Rate Performance:** Assessing the smoothness of real-time rendering, especially in complex scenes;
- **Lighting and Shadow Dynamics:** Evaluating the tools' ability to render realistic lighting and shadows in real-time;
- **Adaptability to VR Constraints:** Exploring how well tools optimize rendering for the computational constraints of VR platforms.

Integration with VR-specific Tools. For a comprehensive virtual reality modeling workflow, integration with VR-specific tools is essential. This subsection explores the level of integration each tool provides with VR-specific functionalities, including:

- **VR Sculpting and Modeling:** Assessing the availability and effectiveness of tools designed specifically for sculpting and modeling in virtual reality;
- **VR-centric Interface Design:** Exploring interfaces that are optimized for VR interactions, promoting a more immersive and natural experience;
- **VR Animation and Interaction Features:** Evaluating tools that support VR-centric animation techniques and user interaction design for virtual environments.

By scrutinizing the compatibility of 3D modeling tools with virtual reality systems, this section aims to guide virtual reality content developers in selecting tools that seamlessly integrate with their VR hardware and provide optimal real-time rendering capabilities. These considerations are pivotal for achieving a cohesive and immersive virtual reality modeling experience.

1.4.3 Case Studies on Tool Utilization

Examining successful applications of 3D modeling tools in virtual reality content creation provides valuable insights into the capabilities and effectiveness of these tools. Case studies may include:

- Immersive VR Games: Showcase how specific tools contributed to the development of visually stunning and engaging virtual reality games;
- Architectural Visualization: Explore instances where 3D modeling tools played a pivotal role in creating realistic virtual walkthroughs of architectural designs;
- Educational and Training Simulations: Highlight the use of 3D modeling tools in developing effective and immersive educational content within virtual reality environments.

Challenges Faced and Solutions Employed. The implementation of 3D modeling tools in real-world scenarios is not without challenges. This subsection delves into the challenges faced during the utilization of these tools for virtual reality content creation and the innovative solutions employed to overcome them. Examples may include:

- Hardware Limitations: Addressing challenges related to the limitations of VR hardware and optimizing content for performance;
- Collaborative Workflow Issues: Detailing challenges in collaborative projects and the adoption of tools or practices to enhance teamwork;
- Complex Scene Rendering: Discussing difficulties in rendering complex scenes in real-time and the implementation of strategies to maintain visual fidelity.

By presenting these case studies, this section aims to provide a practical understanding of how 3D modeling tools contribute to successful virtual reality content creation while addressing and overcoming challenges. The insights derived from these real-world examples serve as valuable lessons for content developers and shed light on

the dynamic nature of 3D modeling tool utilization in the ever-evolving landscape of virtual reality.

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1.4.4 Emerging Trends in 3D Modeling Software

Integration of Artificial Intelligence. Artificial Intelligence (AI) is increasingly playing a transformative role in shaping the future of 3D modeling software. This subsection explores emerging trends related to the integration of AI, focusing on two key aspects:

AI-assisted Modeling. The incorporation of AI-assisted modeling involves leveraging machine learning algorithms to enhance the modeling process. This includes:

- Automated Asset Generation: Exploring tools that use AI algorithms to generate base assets or assist in the early stages of model creation;
- Smart Suggestions and Predictive Modeling: Assessing features that provide intelligent suggestions based on user behavior and optimize the modeling workflow.

Generative Design Capabilities. Generative design takes advantage of AI algorithms to explore a multitude of design possibilities, resulting in innovative and optimized solutions. Considerations include:

- Algorithmic Design Exploration: Evaluating tools that use AI to generate a variety of design options based on specified parameters;
- Optimization for VR Environments: Assessing how AI-driven generative design can optimize models for enhanced performance in virtual reality.

Cloud-Based Collaboration and Workflows. Cloud-based collaboration is becoming integral to modern 3D modeling workflows, offering enhanced flexibility and scalability. This subsection explores trends related to cloud-based collaboration and workflows:

Remote Collaboration Tools. The trend of remote collaboration tools involves features that facilitate teamwork irrespective of geographical locations. This includes:

- Real-time Collaboration Environments: Evaluating tools that enable multiple users to work simultaneously on the same project in real-time;
- Virtual Workspaces: Exploring the creation of virtual workspaces that enhance remote collaboration and project management.

Cloud Rendering Services. Cloud rendering services aim to offload the computational load of rendering from local machines to cloud servers. Considerations include:

- Scalable Rendering Solutions: Assessing tools that allow users to harness the computational power of the cloud for high-quality and efficient rendering;
- Cost-Effective Rendering: Exploring cloud-based rendering solutions that provide cost-effective alternatives for resource-intensive rendering tasks;
- VR-native Modeling Features.

With the growing emphasis on virtual reality, tools are evolving to incorporate features specifically designed for VR content creation. This subsection explores trends related to VR-native modeling features:

Sculpting and Modeling in VR. The trend of sculpting and modeling in VR involves tools that provide a direct and immersive interface for 3D content creation:

- VR Sculpting Tools: Evaluating features that allow artists to sculpt and shape models in a virtual environment using VR controllers;
- Dynamic VR Workflows: Exploring tools that enable dynamic and interactive workflows, enhancing the creative process within VR.

VR-specific Interface Design. Interface design tailored for VR environments is becoming crucial for user interaction and creativity. Considerations include:

- Intuitive VR Interfaces: Assessing how tools design their interfaces to be intuitive and user-friendly within virtual reality;
- Gesture-Based Controls: Exploring the implementation of gesture-based controls for a more natural and immersive modeling experience.

By examining these emerging trends, this section aims to provide insights into the future direction of 3D modeling software, emphasizing advancements in AI integration, cloud-based collaboration, and VR-native features. These trends anticipate a more dynamic and efficient landscape for 3D modeling in virtual reality content creation.

2 ANALYSIS OF THE APPLICATIONS OF VIRTUAL REALITY TECHNOLOGY IN SIMULATION

2.1 Virtual Reality technology

Virtual Reality technology is a new research field that emerged in the 1990s, alongside multimedia and network technologies, and is considered one of the three most promising computer technologies. It has been a hot topic in the technology industry both domestically and internationally in recent years. Virtual reality is a science that integrates human and information, and its core is the computer-generated three-dimensional interactive virtual environment. These environments can be real or abstract and their purpose is to represent information through artificially synthesized experiences. Its essence is to comprehensively simulate reality or fictional worlds using computers, thereby generating a realistic feeling world that integrates three-dimensional visual, auditory, tactile, and even olfactory sensations, allowing users to browse and interact with the virtual world objects generated from their perspective, utilizing natural skills and some equipment. With Virtual Reality technology, it is possible to present complex or abstract concepts in a virtual form in people's sensory space.

Virtual Reality technology is a comprehensive technology that involves computer graphics technology, human-computer interface technology, multimedia technology, sensing technology, highly parallel real-time computing technology, stereo vision, and artificial intelligence, among other new technologies. It provides great convenience for humans to explore the macro world, the micro world, and situations where they cannot observe or participate in motion changes for various reasons.

In summary, Virtual Reality can be considered an advanced human-machine interface that allows people to experience designer's thoughts through visual, auditory, tactile, and even olfactory information channels. It is a new form of human-computer interaction and a higher level of multimedia development. The model of Virtual Reality is shown in Figure 2.1.

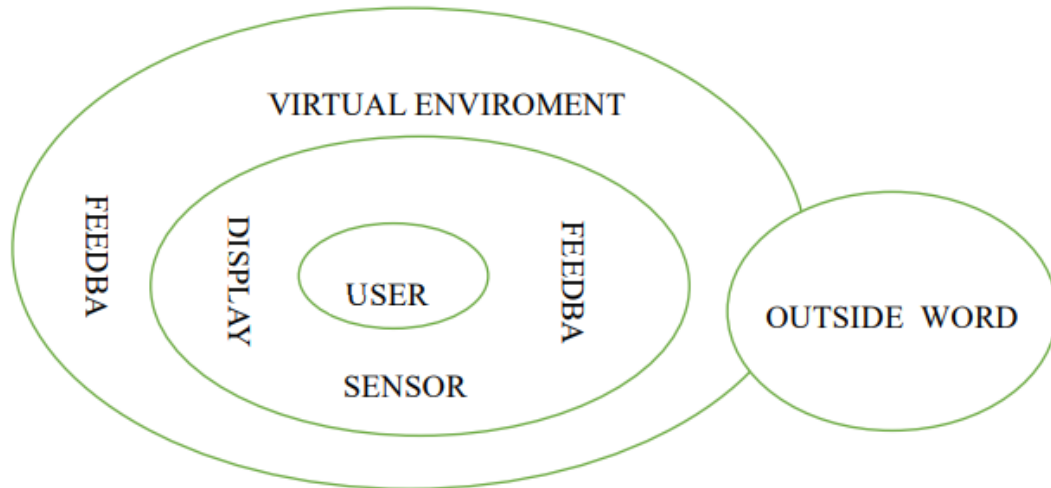


Figure 2.1 – Model of Virtual Reality

Virtual reality has three important characteristics, known as the three "I" features [16-20]: immersion, interaction, and imagination, as shown in Figure 2.2.

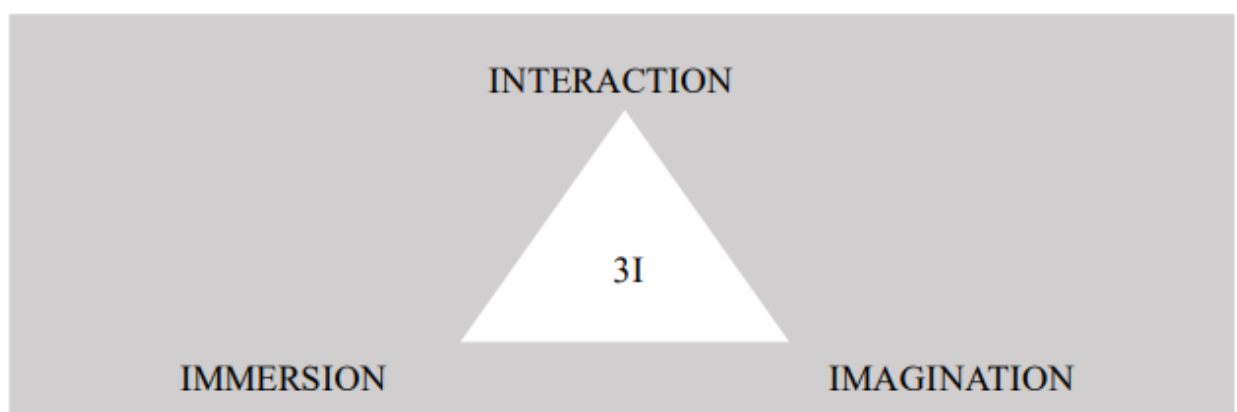


Figure 2.2 – The 3 I features of virtual reality, namely Immersion, Interaction, and Imagination

One of the purposes of virtual reality is to make users feel like they are a part of the virtual environment created by the computer system, transforming them from mere

observers to active participants who can fully immerse themselves in the virtual world. The degree to which users feel like they are the main character in the virtual environment is an important indicator of virtual reality. Virtual reality creates a highly realistic and convincing illusion of a world that can deceive our human senses in multiple ways, allowing us not only to see but also to hear, touch, and even smell everything that happens in this virtual world. This feeling is so real that we can fully immerse ourselves in this imaginary world, which is the primary characteristic of virtual reality, namely immersion.

Virtual reality is different from ordinary multimedia environments. It is not a static world but an open environment that can respond to users' inputs such as gestures, voice commands, or keyboard and mouse operations. In the system, users can directly control various parameters of objects such as motion direction and speed, while the system can also provide feedback to users. Although this interactivity may seem like a technical change, it has caused a revolutionary shift in people's perceptions of the computer world: the idea of "computers as the subject" has gradually been abandoned, and most people have come to accept the idea that "people are the subject of the information environment". We can affect the virtual reality environment through control and monitoring devices, which is the second characteristic of virtual reality, namely interactivity.

2.2 Virtual Reality System

The hardware components of a basic virtual reality system mainly include: a main computer used to generate various virtual reality scenes and perform real-time calculations and processing; a visual display device (such as a helmet display or computer screen) for people to observe and experience the virtual reality environment; and data input devices (such as data gloves or keyboards, mice, etc.) used to interact with the virtual reality environment [16~20].

In the process of designing and developing virtual reality systems, the use of different software and hardware devices results in different effects of the final virtual reality systems. According to different forms of user participation and levels of immersion, various types of virtual reality systems can be classified into four categories [16-20].

Immersive virtual reality system. Advanced immersive virtual reality systems provide a fully immersive experience, giving users a feeling of being immersed in a virtual world. It uses a helmet-style display or other devices to enclose the participant's visual, auditory, and other senses, and provide a new virtual sensory space. It uses position trackers, data gloves or other hand-controlled input devices, as well as sound and images to create a feeling of immersive involvement. Common immersive virtual reality systems include helmet-based display systems, projection-based virtual reality systems, and remote presence systems.

Augmented reality virtual reality system Augmented reality virtual reality not only uses virtual reality technology to simulate or replicate the real world, but also enhances the participant's perception of the real environment, enhancing the perception that cannot be obtained or is inconvenient to obtain in reality. A typical example is the heads-up display for fighter pilots, which can project instrument readings and weapon aiming data onto the penetrable screen installed in front of the pilot, so that the pilot does not have to look down to read instrument data and can focus on observing enemy aircraft and navigation deviations.

Distributed virtual reality system. If multiple users are connected together through a computer network, and participate in a virtual space together to share the virtual experience, then virtual reality is elevated to a higher level, which is a distributed virtual reality system. In a distributed virtual reality system, multiple users can observe and operate the same virtual world through the network, in order to achieve the goal of collaborative work. Currently, the most typical distributed virtual reality system is SIMNET, which is composed of tank simulators connected through a network for joint military training. Through SIMNET, simulators located in Germany can run in the same

virtual world as simulators located in the United States, participating in the same combat exercise.

Desktop Virtual Reality Systems. Desktop Virtual Reality Systems simulate using personal computers and low-level workstations, with the computer screen serving as the user's window to observe the virtual world. Various input devices, including mice, keyboards, tracking balls, and force balls, are used to interact fully with the virtual environment. It allows participants to observe a virtual environment within a 360-degree range through the computer screen and manipulate objects within the virtual scene using input devices. However, at this point, participants lack a complete sense of immersion since they are still affected by the real-world environment around them. However, due to their relatively low cost, desktop virtual reality systems are widely used. Common desktop virtual reality systems include virtual reality based on VRML (Virtual Reality Modeling Language), QuickTime VR based on static images, desktop 3D virtual reality, MUD, and others.

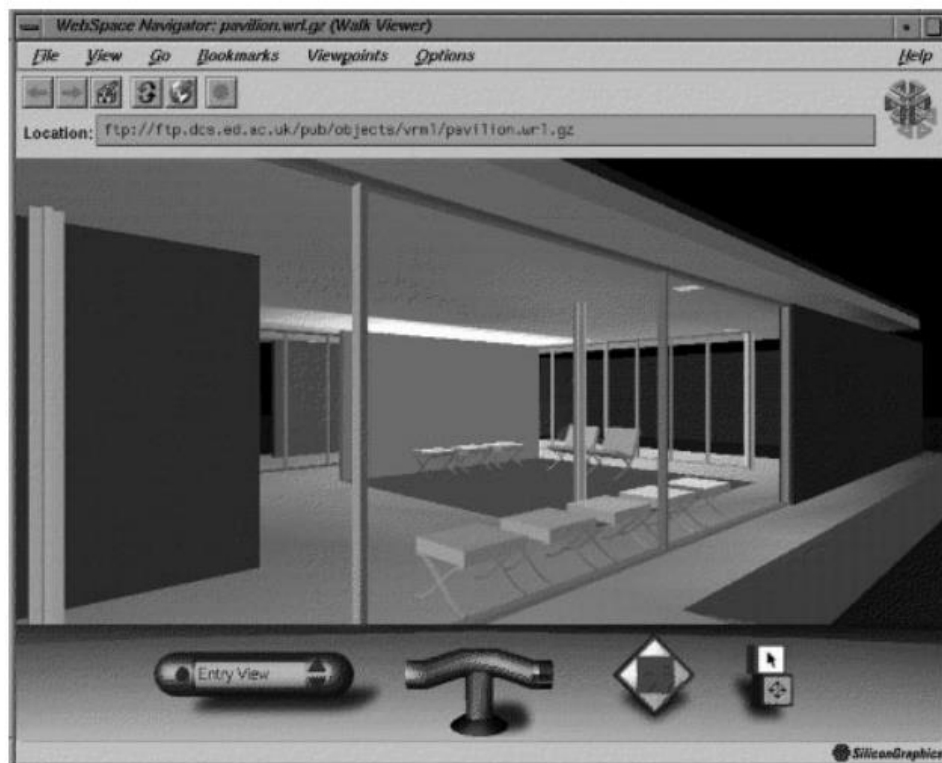


Figure 2.3 – VRML model

From the above discussion, it can be seen that virtual reality technology not only includes technologies related to helmet displays and data gloves but also includes all technologies and methods related to natural simulation and realistic experience. The fundamental purpose of virtual reality is to obtain a real experience and natural skill-based human-computer interaction. Any system that can achieve or partially achieve this goal can be called a virtual reality system.

2.3 Applicability of Virtual Reality Technology

Virtual reality technology emphasizes on presentation, while system simulation emphasizes on scientific abstraction of complex systems and truly reflects the motion of the target system. System simulation technology can be used as a dynamic method for object behavior in virtual reality environments and can be considered as one of the fundamental technologies of virtual reality. Virtual reality technology can be used as an advanced tool for simulation visualization and human-computer interaction. By using virtual reality technology, the validity of the simulation model can be better verified and the simulation system can be better presented, allowing users to have a more intuitive and sensory understanding of the simulation model, thus achieving better simulation results. Therefore, virtual reality and system simulation are closely related and complementary fields.

Since the advent of computers, human-computer interaction interfaces have gone through several stages, including command-line interfaces, graphical user interfaces, and multimedia interfaces. The rapid development of graphical interaction technology fully demonstrates that making the objects easy to operate and visually intuitive is a very important issue for applications. People's living space is inherently three-dimensional, although graphical user interfaces (GUIs) have provided some "pseudo-3D" interface elements, they are essentially a static, single-channel human-computer interface.

Virtual reality technology has real-time 3D spatial performance capability, and can achieve a person-centered human-computer interaction method. Virtual reality environments can give users a sense of immersion, which changes the boring, stiff, and passive relationship between people and computers. It not only creates new interaction forms between people and computers in the simulation system but also provides new methods for visualizing simulation processes and results. At the same time, it also provides great convenience for people to explore the macro and micro world or the motion and variation laws of things that are not easy to observe directly due to various reasons.

In summary, virtual reality technology has created excellent conditions for establishing a convenient, natural, and intuitive human-computer interaction method.

In theory, combining virtual reality technology with simulation technology can result in a virtual reality simulation system. However, this combination is not simply an addition of the two types of systems, but rather an organic entity that integrates the characteristics of both. Virtual reality systems are based on simulation, and for virtual reality systems, the core is the simulation engine. Virtual reality systems rely on the simulation engine to drive the passage of time in the virtual world, handle interactive events, simulate object behavior, simulate natural laws, and determine the state of the virtual world. For system simulation, whether simulating the real world or a fictional world, virtual reality technology can be used as a three-dimensional representation of the simulation model and simulation result data, realizing advanced human-machine interfaces in simulation systems.

2.4 Limitations of Virtual Reality Technology

The application of virtual reality technology can indeed bring many benefits, especially the immersion and interactivity provided by virtual reality systems, which allow users to freely move and browse in virtual worlds, control objects in the virtual

world to influence its state, and directly observe and solve problems. However, virtual reality technology cannot solve all problems and cannot replace all methods and means in the simulation process. The three main features of virtual reality, immersion, interactivity, and imagination, indicate that it is more suitable for describing concrete things and solving micro and detail-oriented problems, but not suitable for expressing logical and mechanical models of systems at a macro and abstract level. Therefore, while virtual reality technology has significant advantages, it also has its limitations.

To what extent is virtual reality technology applicable in simulation? Is everything in the simulation process, including building simulation models, running simulation systems, and analyzing simulation results, suitable for using virtual reality technology to achieve? Currently, most of the materials the author has seen only list a series of areas where virtual reality technology may or has been applied in a general sense, but rarely explore the issue of the applicability of virtual reality technology.

General application problems can be divided into two categories: macro problems and micro problems. From the perspective of practical application, virtual reality technology is not necessarily suitable for solving all problems. From the current application of virtual reality technology, it is basically applied to micro decision-making problems, and the author believes that virtual reality technology is less suitable for macro decision-making problems. Note that the macro and micro referred to here are not related to the physical scale of things, but from the perspective of observing and solving problems.

For example, the application of virtual reality technology in manufacturing simulation, which produces "virtual manufacturing", aims to simulate the manufacturing process of a product on a computer in order to discover and solve various problems that may arise during the manufacturing process. This is a micro decision-making problem. In military simulation and training, for a soldier, he or she needs to observe the surrounding environment and cooperate with teammates to achieve the best results, which is a personal micro decision-making problem. However, for a commander, he or she needs to command troops and make macro decisions for the whole team. If the commander is also put on the virtual battlefield to observe firepower, he or she will not

be able to oversee the whole situation and formulate strategic decisions from the overall perspective, which will undoubtedly lead to failure.

In the system simulation of process industries, when building a simulation model, the modeling personnel are concerned with whether the connection between devices is correct and whether the entire process is logical, which is a macro decision-making problem. At this time, the modeling personnel do not care about micro decision-making problems such as whether the appearance of the devices is similar to those in the real world. Therefore, in this case, it is unnecessary and not suitable to use virtual reality technology to express the simulation modeling process. Two-dimensional graphics modeling has greater advantages because of its intuitive, simple, and easy-to-grasp characteristics from an abstract logical level for the target system's simulation model.

The main reason why virtual reality systems are not suitable for macro decision-making problems is that it is difficult to establish a three-dimensional model for macro problems, and macro decision-making is not about intuitive or detailed issues. Even if an abstract three-dimensional model can be established, its significance for solving problems is not significant. Perhaps it only adds some interest, and it is better to use a more intuitive and efficient two-dimensional model.

Therefore, the superiority of the relatively abstract two-dimensional graphical representation is also a major limitation of virtual reality, that is, "getting lost." When wandering and browsing in virtual reality, it is often easy to feel "lost" and not know where one is. As the saying goes, "One does not recognize the true face of Mount Lu, only because one is in this mountain." Because of the immersive feeling of virtual reality, users are unable to grasp the overall picture of the object being studied from an abstract concept level. When users are immersed in virtual reality, they mainly perceive the local details of the system. Therefore, in virtual worlds, a two-dimensional map is often needed for guidance. For example, many 3D computer games have a map showing the overall overview at the bottom of the screen, which serves as a navigation tool. Players can understand their location through the markers on the map, and they can also move themselves to the desired location by operating the map. It can be seen that in different application scenarios and at different stages of the simulation process, virtual

reality also needs to be combined with other types of representation to achieve the best effect.

2.5 Virtual reality and graphic modelling integration mechanism

The actual system often involves both macro and micro decisions that are sometimes difficult to distinguish, and macro and micro problems can also be transformed into each other in certain situations. In the simulation system of process industry, operators observe the state of equipment in order to make decisions on how to adjust various parameters, which is a micro decision problem; in the simulation modeling process, how to combine a process flow and use various equipment models to build a simulation model of a factory becomes a macro decision problem.

Virtual reality in simulation systems is mainly aimed at presentation and participation . In the display stage of the simulation model, we hope that users can have an intuitive and perceptual understanding of the simulation objects. We want users to see the appearance characteristics of objects in the simulation environment and to know the phenomena that occur when certain events happen. In this case, we should use the three-dimensional virtual scene produced by virtual reality, which has the characteristics of realism, dynamism, and interactivity, to enable users to experience immersive and vivid information that cannot be expressed by other media forms.

In the simulation modeling stage, users need to understand the process flow of a factory from the conceptual level and grasp the simulation model from the abstract level. The modeling personnel are primarily concerned with the correctness at the logical level, rather than the similarity in appearance, which belongs to the macro decision problem. In this case, graphic modeling can be used to express the simulation model more concisely and intuitively. Therefore, in this project, based on the advantages and disadvantages of virtual reality technology and graphic modeling technology, they are combined and applied to the simulation process of process industry

systems, complementing each other's shortcomings. For the simulation modeling stage, graphic modeling is used, while virtual reality technology is used in the simulation model display stage. The organic combination of the two achieves good application results. Of course, the application of these two technologies in simulation is not isolated from each other, they are interconnected and have data dependency.

3 PLANNING THE 3D MODELING PROCESS

3.1 Statement of the Project Task

The goal of the project is to create a virtual demonstrative 3D model of the online store's product. I choose a Water Bottle as such a product.

A demonstrative 3D model for an online store is a digital representation of a product that users can interact with in a three-dimensional space. Unlike traditional 2D images, these 3D models allow potential customers to view the product from various angles, zoom in to examine details, and even rotate it for a comprehensive look. They are particularly valuable for showcasing products with intricate designs, textures, and features.

The advantages of incorporating demonstrative 3D models in virtual stores are manifold. Firstly, they offer a more immersive and engaging shopping experience by providing customers with a closer, more interactive inspection of the product. This enhanced visualization can lead to increased customer confidence and a better understanding of the item's form and function.

Moreover, the ability to zoom in and rotate the 3D model enables customers to scrutinize finer details, fostering a sense of transparency and trust in the online shopping process. This can contribute to a reduction in product returns, as customers are more likely to make informed decisions based on their thorough examination of the digital model.

Some online retailers take it a step further by implementing Augmented Reality (AR) technology. This allows customers to virtually place the 3D model of the product in their own physical space using their smartphones or other AR-enabled devices. This augmented experience provides an even more tangible sense of how the product will fit into the customer's life, potentially boosting confidence in their purchase decisions.

In conclusion, the integration of demonstrative 3D models, especially in conjunction with AR technology, represents a cutting-edge approach to online retail. It not only enhances the customer's ability to evaluate a product but also contributes to a more engaging and satisfying shopping experience.

Reusable water bottles are containers designed for multiple uses with the primary purpose of reducing the consumption of single-use plastic bottles and promoting sustainable hydration practices. These bottles are crafted from various materials, each offering distinct advantages in terms of durability, portability, and eco-friendliness.

Materials:

- Plastic: Reusable water bottles can be made from durable and recyclable plastics, such as BPA-free polyethylene or polypropylene. These materials ensure longevity while minimizing environmental impact;
- Stainless Steel: Stainless steel bottles are known for their robustness and ability to keep beverages at desired temperatures. They are resistant to corrosion and provide a sleek and modern aesthetic;
- Glass: Glass bottles offer a clean and pure taste to the stored liquids. They are a preferred choice for those who prioritize the absence of any potential leaching from plastic or metal materials.

Purpose: The primary purpose of reusable water bottles is to reduce the reliance on disposable plastic bottles, thus contributing to environmental conservation. By encouraging individuals to carry and refill their bottles, these products aim to minimize plastic waste, conserve resources, and promote a more sustainable lifestyle. Additionally, reusable bottles promote proper hydration, offering a convenient and eco-conscious alternative for individuals on the go.

Features:

- Leak-Proof Designs: Many reusable bottles come with advanced sealing mechanisms to prevent leaks and spills, making them suitable for various activities, including sports and commuting;
- Insulation: Some bottles have insulation properties, either keeping beverages hot or cold for extended periods, enhancing their versatility for different climates and preferences;
- Eco-Friendly Practices: Manufacturers often emphasize eco-friendly production processes and materials, aligning with the values of environmentally conscious consumers;
- Customization: Reusable water bottles are available in a variety of sizes, shapes, and colors, allowing users to choose options that suit their personal style and preferences.

Reusable water bottles are sustainable alternatives to single-use plastics, designed to promote environmental responsibility and healthy hydration practices. The diverse range of materials and features caters to the varied needs and preferences of consumers committed to reducing their ecological footprint.

Create a 3D model for the reusable bottle that allows potential buyers to see its design, functionality and other features in detail. This can include realistic details such as textures, a lid with a special lock, or functionality that can be displayed in 3D, such as folding for easy cleaning or other innovative solutions.

Developing a high-quality 3D model can greatly facilitate your product's online sales by giving customers the opportunity to see it from all angles and discover all the benefits before purchasing it.

3.1.1 Project Requirements

One of the actual products of the online store is chosen as a prototype.

The model must be solid-state. The model must contain the number of bodies corresponding to the number of product parts.

Each body of the model should be assigned a corresponding material and color.

Bodies made of glass and transparent plastic must transmit light.

The model format must allow its visualization.

The model format must allow for online publication.

3.1.2 Input Data

As input, we use a prototype from a real online store. To do this, we go to the address of the online store (Figure 3.1) and select one of the models as a prototype (Figure 3.2).

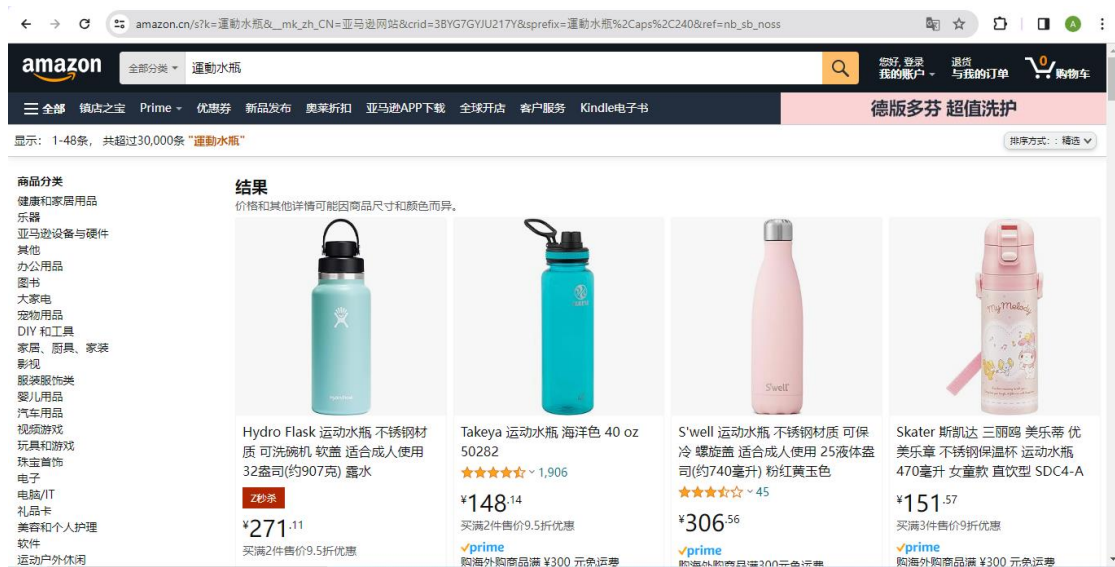


Figure 3.1 – Selecting a prototype for model execution using the online store interface



Figure 3.2 – Prototype for 3D model creation

3.2 Selection of Equipment for Project Implementation

To implement the project, we will use a comprehensive combination of two programs:

- Siemens NX 1872;
- Luxion Keyshot 9.

For educational purposes, I use the educational versions of these programs. Below is a brief description of these programs:

NX, developed by Siemens Digital Industries Software, is a comprehensive solution widely utilized in industrial design for creating 3D models and visualizing products. Its robust features make it an indispensable tool for designers and engineers in various industries, providing advanced capabilities for both conceptualizing and realizing complex products.

Key Features for Industrial Design:

- Parametric 3D Modeling: NX excels in parametric 3D modeling, allowing designers to create precise and flexible models. This is crucial in industrial design where accuracy and adaptability are paramount;
- Assembly Design: The software facilitates the assembly of complex components, enabling designers to simulate how different parts fit together. This feature is vital for industrial designers working on intricate products with multiple components;
- Surface Modeling: For creating aesthetically pleasing and ergonomic designs, NX offers powerful surface modeling tools. This is particularly beneficial for industrial designers focused on the visual and tactile aspects of product development.

NX supports digital prototyping, allowing designers to virtually test and validate their concepts before physical prototypes are produced. This accelerates the design iteration process and reduces costs.

NX is a versatile and powerful software solution for industrial design, offering a suite of tools that empower designers to create, visualize, and optimize 3D models. Its

capabilities in parametric modeling, surface design, and product visualization make it an ideal choice for those engaged in industrial design across diverse sectors.

KeyShot, developed by Luxion, is a powerful and user-friendly 3D rendering and visualization software designed to create high-quality, photorealistic images from 3D models quickly. It is widely used in industries such as product design, engineering, marketing, and more, providing a streamlined workflow for users to turn their 3D models into stunning visuals.

Key Features:

- Real-Time Ray Tracing: KeyShot employs real-time ray tracing, allowing users to see changes to lighting, materials, and cameras instantly. This feature facilitates quick iterations and a more efficient rendering process;
- Library of Materials and Environments: The software includes a vast library of materials, textures, and environments. Users can drag and drop these elements onto their models, simplifying the process of achieving realistic and varied visual effects;
- Advanced Lighting and Illumination: KeyShot offers advanced lighting capabilities, including accurate global illumination and HDR (High Dynamic Range) lighting. This contributes to the creation of scenes with lifelike reflections and shadows;
- Animation and Scripting: Users can create animations directly within KeyShot, enabling them to showcase product functionality or design variations. The software supports both simple and complex animations. Additionally, scripting capabilities provide automation options for repetitive tasks;
- VR Headset Support: KeyShot supports virtual reality (VR) experiences by allowing users to create and view VR-ready content. This is particularly valuable for immersive presentations and design reviews;
- Multi-Material and Multi-layered Materials: The software supports the application of multiple materials to a single model and allows for the creation of complex, multi-layered materials. This flexibility enhances the realism of rendered images;

- Cloud Rendering: KeyShot provides cloud rendering capabilities, enabling users to offload rendering tasks to the cloud for increased speed and efficiency, particularly when dealing with resource-intensive scenes;
- Compatibility: KeyShot supports a wide range of 3D file formats, making it compatible with major 3D modeling software. This interoperability facilitates a smooth workflow for users working across different platforms.

Applications: KeyShot finds applications in various industries, including product design, automotive design, marketing, architecture, and more. Its ease of use and ability to deliver visually compelling results make it a popular choice for professionals seeking to visualize their 3D designs in a realistic manner.

3.3 Algorithm of the 3D Modeling Process

In my case, the algorithm for creating a 3D model will look like this:

- Select a plane to create a sketch;
- Create a sketch;
- Create a solid using a sketch;
- Create chamfers and roundings;
- Create the rest of the model's solids.

The 3D modeling process is iterative, with designers often revisiting various stages to achieve the desired result. It involves a combination of artistic creativity and technical proficiency to bring virtual objects to life.

4 DEVELOPMENT OF THE 3D MODEL

4.1 Creating the Model

To create a 3D model, create the appropriate model file and select its location on my computer (Figure 4.1).

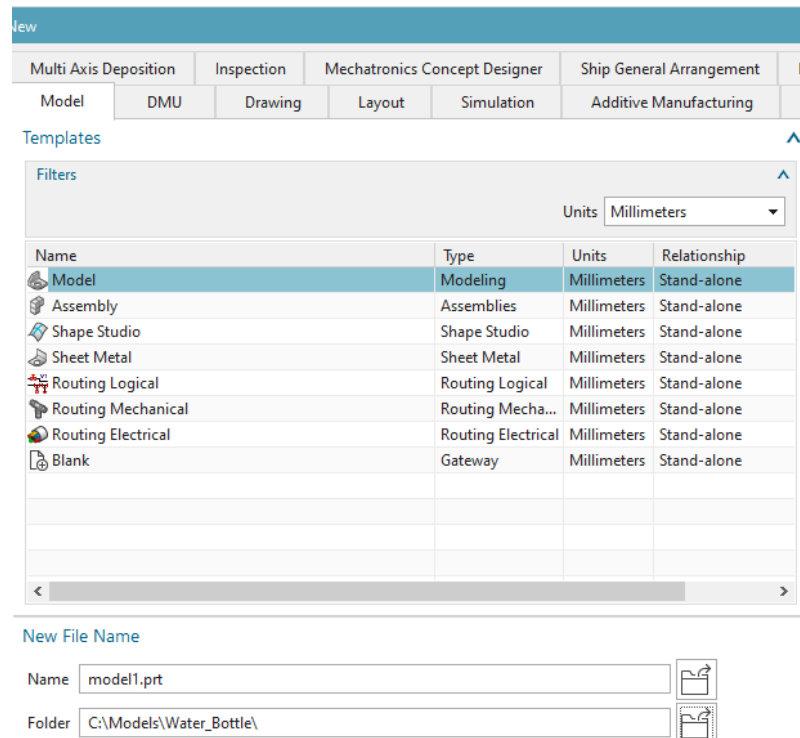


Figure 4.1 – Window with the menu for creating a 3D model

Next, create the first sketch (Figure 4.2). To create a sketch, select the appropriate coordinate plane.

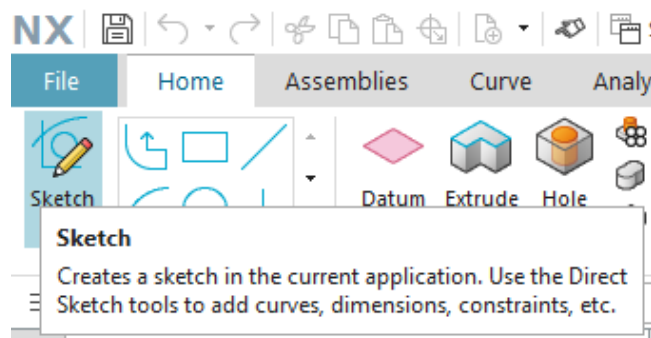


Figure 4.2 – Sketch creation command

Sketch is a 2D graphical representation that serves as the foundation for creating a 3D model. The sketch defines the shape and dimensions of an object within a single plane and can include geometric elements such as lines, curves, circles, and other shapes.

Key features of a sketch in NX include:

- Sketch Plane: The sketch is positioned on a specific plane in space, such as the XY, XZ, or YZ plane, depending on the requirements;
- Geometric Objects: Various geometric elements can be added to the sketch, including lines to define contours, curves for complex shapes, circles, rectangles, and more;
- Dimensions and Distances: The sketch may include dimensions and distances that determine the sizes and spatial relationships of different elements in the sketch;
- Orientation and Reference Lines: Adding orientation lines and points can facilitate the creation of the sketch and indicate important aspects of the design.

The sketch acts as a basis for further 3D modeling. In NX, you can use sketches to define profiles that can be extruded, revolved, sliced, and interact with other modeling features to create a fully realized 3D model.

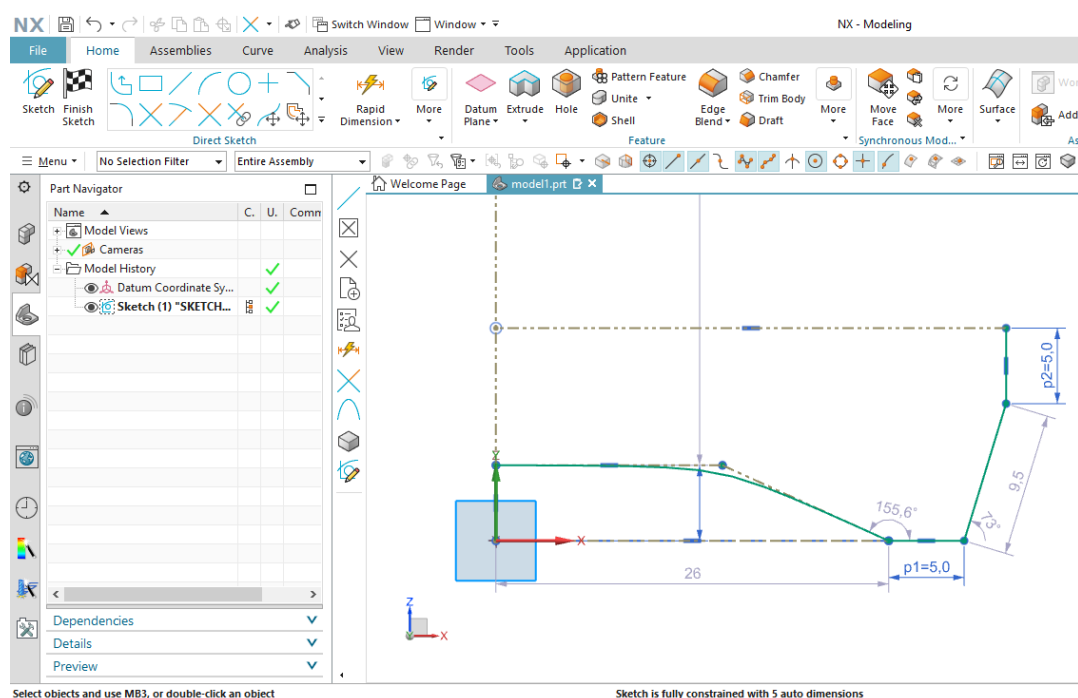


Figure 4.3 – The process of sketching

Next, we use the created sketch to create the first body using the revolve operation.

The revolve operation is a pivotal process employed for transforming 2D sketches into three-dimensional objects. This operation allows users to create symmetrical shapes by rotating a profile around a specified axis, resulting in a solid or surface geometry.

Key Features of the Revolve Operation:

- **Profile Definition:** Users begin by defining a 2D profile within a sketch. This profile serves as the basis for the revolved geometry;
- **Axis Specification:** The revolve operation involves selecting an axis around which the profile will revolve. This axis can be aligned with the global coordinate system or customized based on design requirements;
- **Angle of Revolution:** Designers can specify the angle through which the profile revolves around the axis, determining the extent of the rotation and resulting in a partial or complete revolution;
- **Symmetry:** Revolving a profile often results in symmetrical 3D shapes. This is particularly useful for creating objects such as cylindrical features, cones, or other rotationally symmetric components;
- **Material Removal or Addition:** The revolve operation can be used in various contexts, including material removal (e.g., creating holes through revolved cuts) or material addition (e.g., generating solid bodies through revolved extrusions).

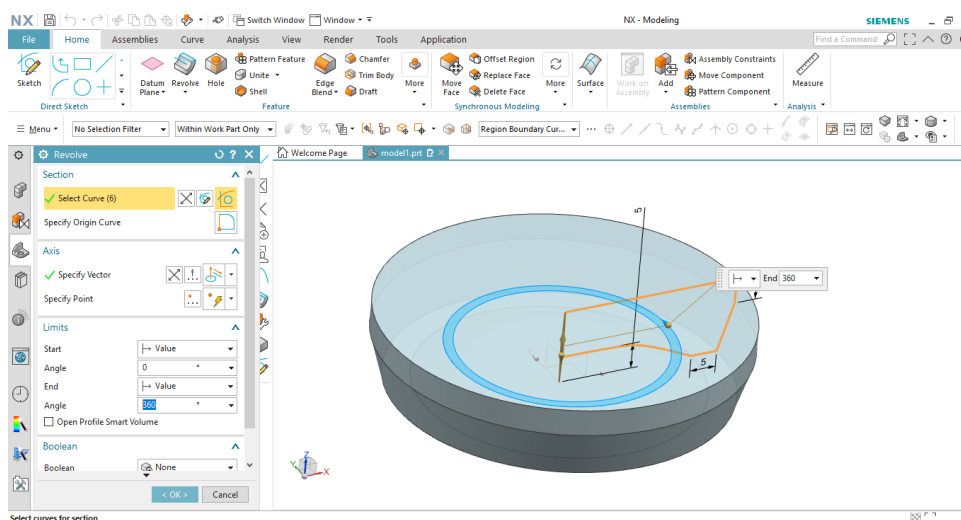


Figure 4.4 – The process of Revolve Operation

Application of Revolve in 3D Modeling:

- Cylindrical Features: Revolving a circular or rectangular profile can create cylindrical features, such as shafts, pipes, or columns;
- Conical Shapes: Profiles with a taper can be revolved to form conical shapes, applicable in designs ranging from funnels to tapered components;
- Rotational Symmetry: Revolve is particularly effective when designing objects with rotational symmetry, as it ensures consistency around the axis of rotation;
- Creation of Revolved Cuts: The operation is not limited to adding material; it can also be used to cut away material from existing shapes, introducing holes or grooves through the revolved cut feature;
- Efficient Design Iteration: Revolve contributes to efficient design iteration by allowing designers to quickly generate complex shapes from simple profiles, fostering a streamlined modeling process.

The revolve operation in NX is a powerful tool for creating rotational geometry, offering designers flexibility and efficiency in transforming 2D sketches into fully realized 3D objects. Its applications range from basic geometric shapes to intricate components with rotational symmetry.

Next, we use the Edge Blend operation (Figure 4.5).

Edge Blend operation is a crucial process for enhancing the appearance, functionality, and safety of 3D models. This operation is also commonly referred to as filleting or rounding edges. The Edge Blend feature creates smooth transitions between adjacent surfaces or edges, providing a visually appealing and physically robust design.

Key Aspects of the Edge Blend Operation:

- Edge Selection: Users begin by selecting the edges on the 3D model that they wish to blend. These edges can be the intersection of two surfaces or the edges of a solid body;
- Radius Specification: The Edge Blend operation requires specifying a radius or a fillet size, determining the curvature of the blended region. This radius influences the visual aesthetics and functional aspects of the design;

- Tangent or Curvature Continuity: Designers can choose between tangent or curvature continuity for the blend. Tangent continuity ensures a smooth transition in terms of slope, while curvature continuity ensures a smooth transition in terms of curvature, resulting in a more natural and aesthetically pleasing blend;
- Variable Radius Blending: In some cases, variable radius blending may be employed, allowing for different fillet sizes along a single edge. This is beneficial for achieving specific design requirements;
- Full or Partial Edge Blending: The operation provides the flexibility to blend the entire length of an edge or only a specified portion. This is useful for addressing design constraints or achieving a desired visual effect.

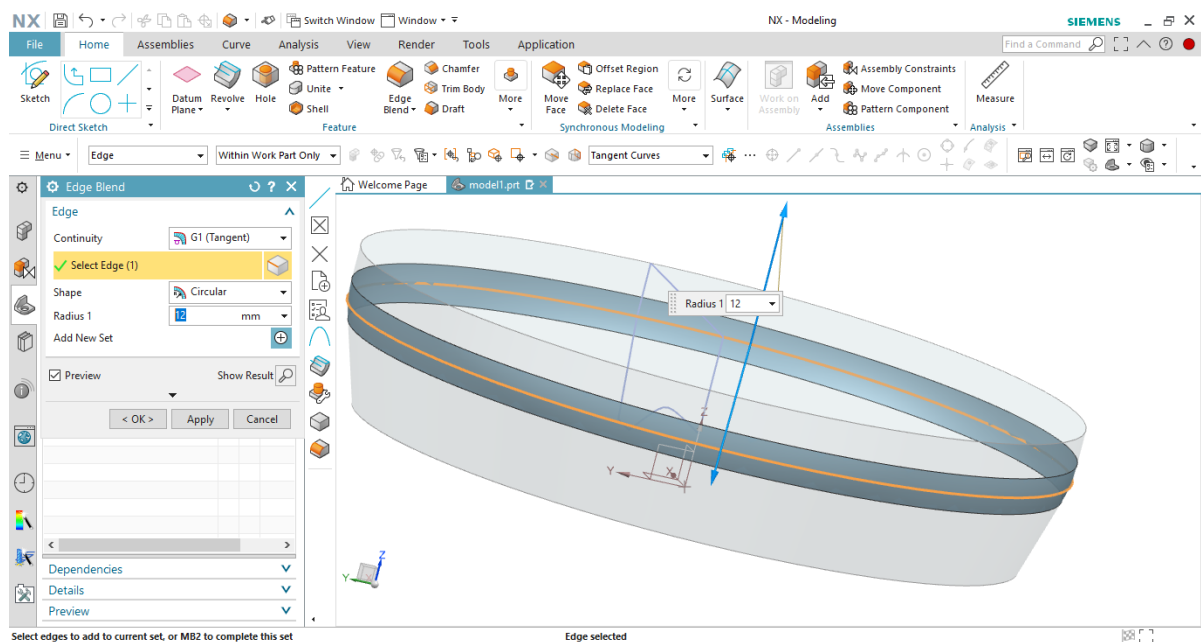


Figure 4.5 – The process of Edge Blend Operation

In the next operation, we create the next solid using the Revolve Operation (Figure 4.6).

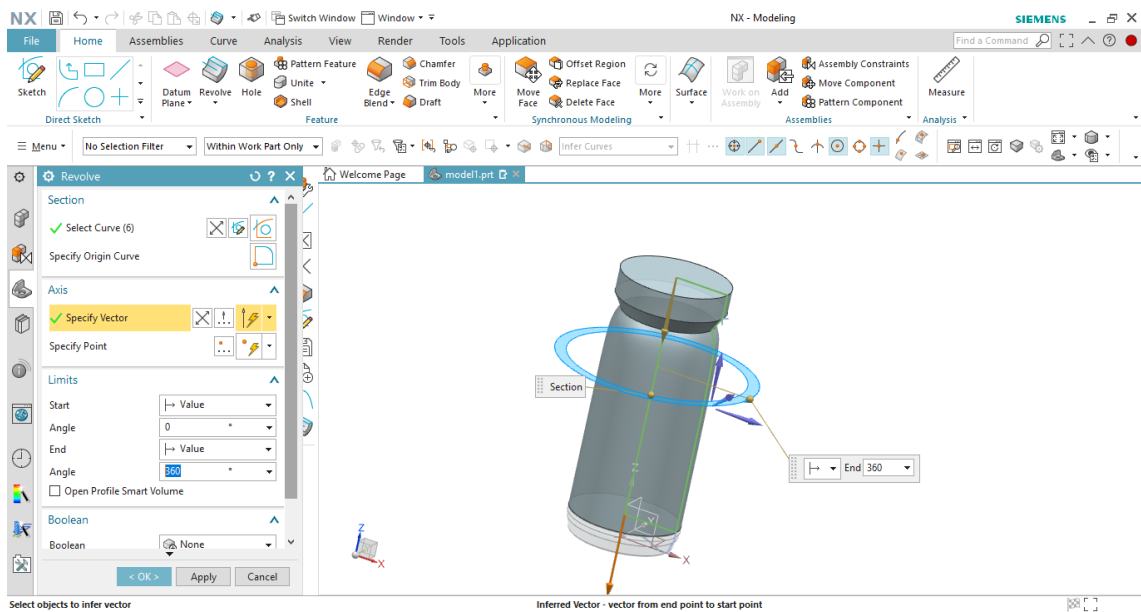


Figure 4.6 – The process of Revolve Operation

In the next step, create Edge Blend between the surfaces of the body of the Water Bottle 3D-model (Figure 4.7).

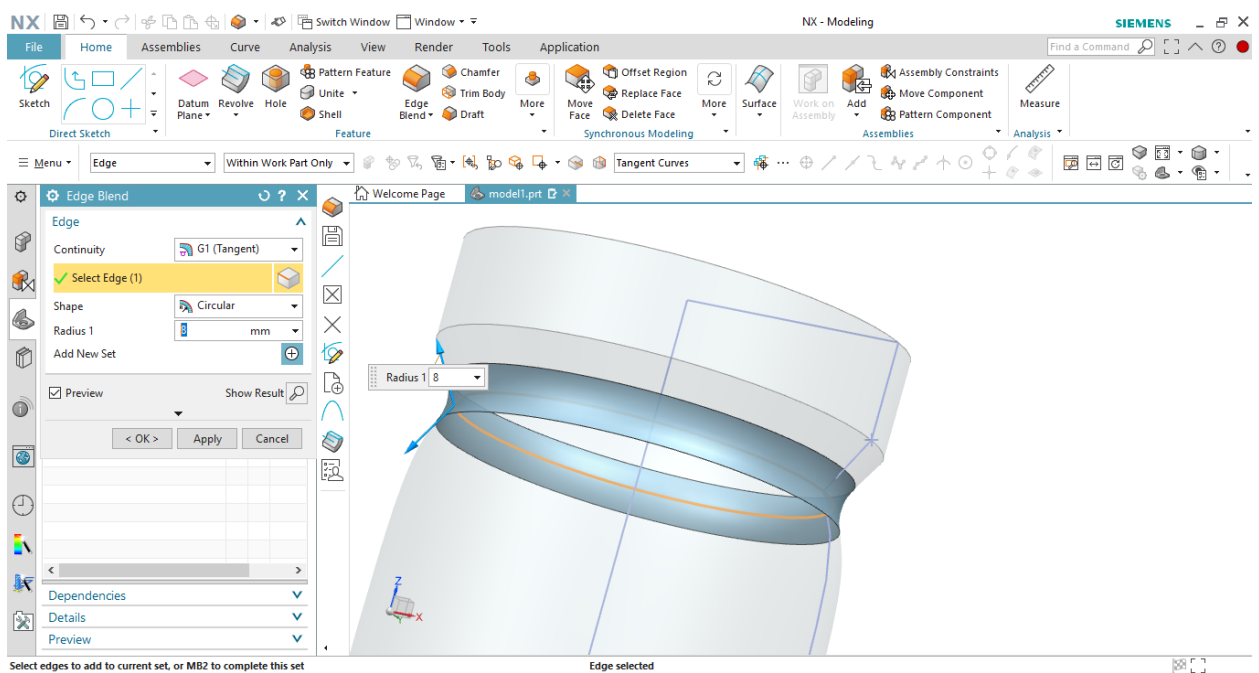


Figure 4.7 – Edge Blend Operation

Then we create an auxiliary datum plane (Figure 4.8). For this purpose, select the base coordinate plane and the distance from it.

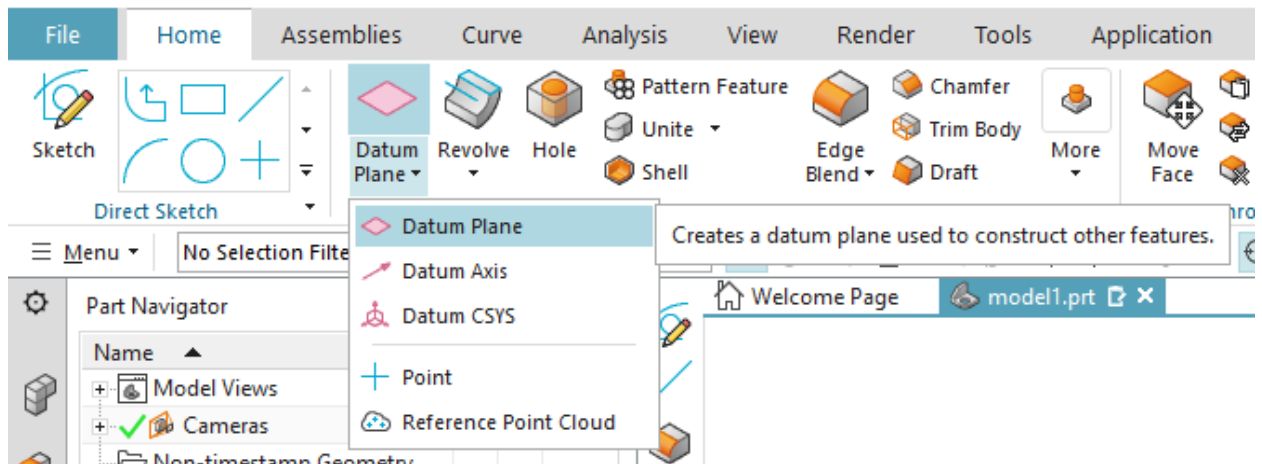


Figure 4.7 – Auxiliary Datum Plane command

The Datum Plane command in NX is a tool that allows users to create virtual planes in space for further modeling operations. These planes define the position and orientation relative to existing elements of the model, aiding in refining geometric parameters.

Users can create a plane at any location in 3D space using this command. The plane can be positioned parallel, perpendicular, or at an angle to existing model elements such as axes, surfaces, or edges. Users can define the plane by specifying points or other geometric objects in space.

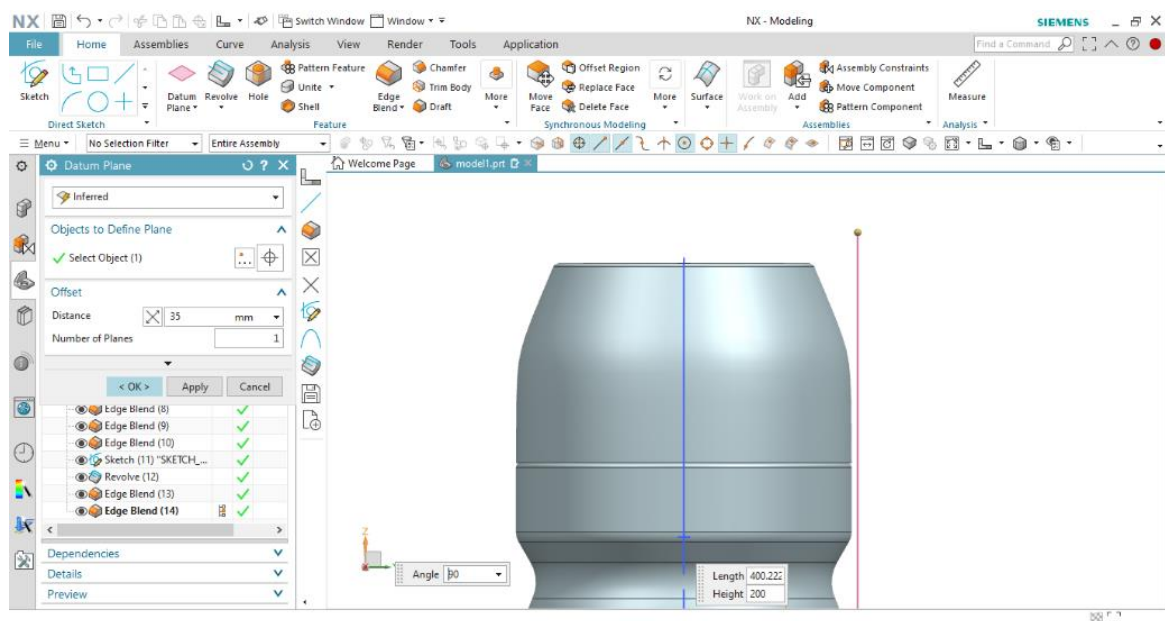


Figure 4.8 – Datum Plane

The auxiliary plane is necessary to build the mounting point for the water bottle handle. Then we create a sketch on the auxiliary plane (Figure 4.9)

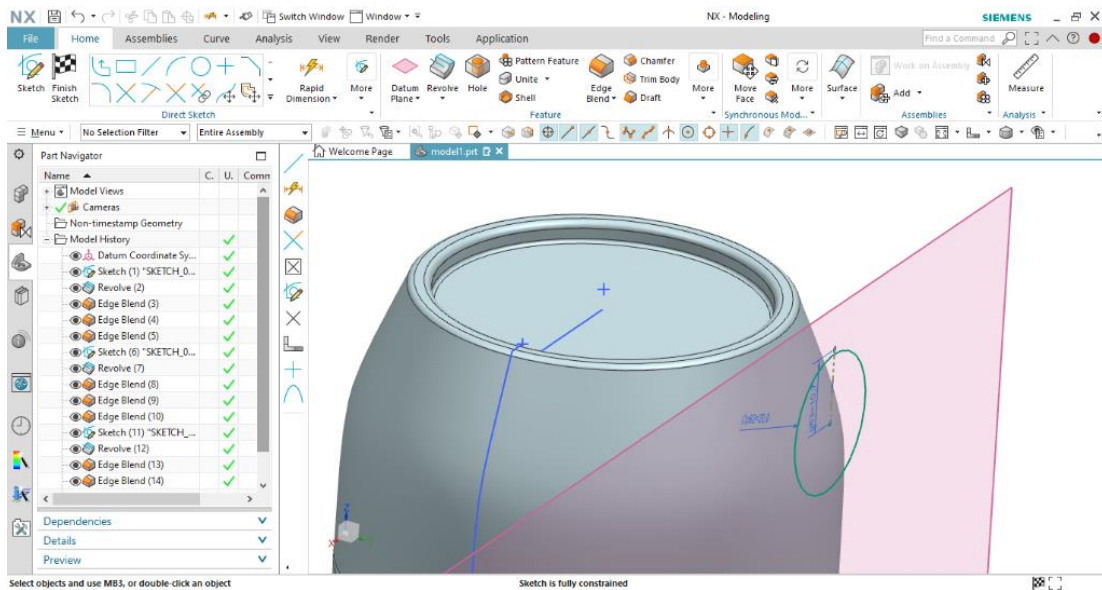


Figure 4.9 – Creation a sketch on the Datum Plane

Then we use a Extrude operation. The Extrude operation in NX is a fundamental tool for transforming 2D sketches into fully realized 3D models.

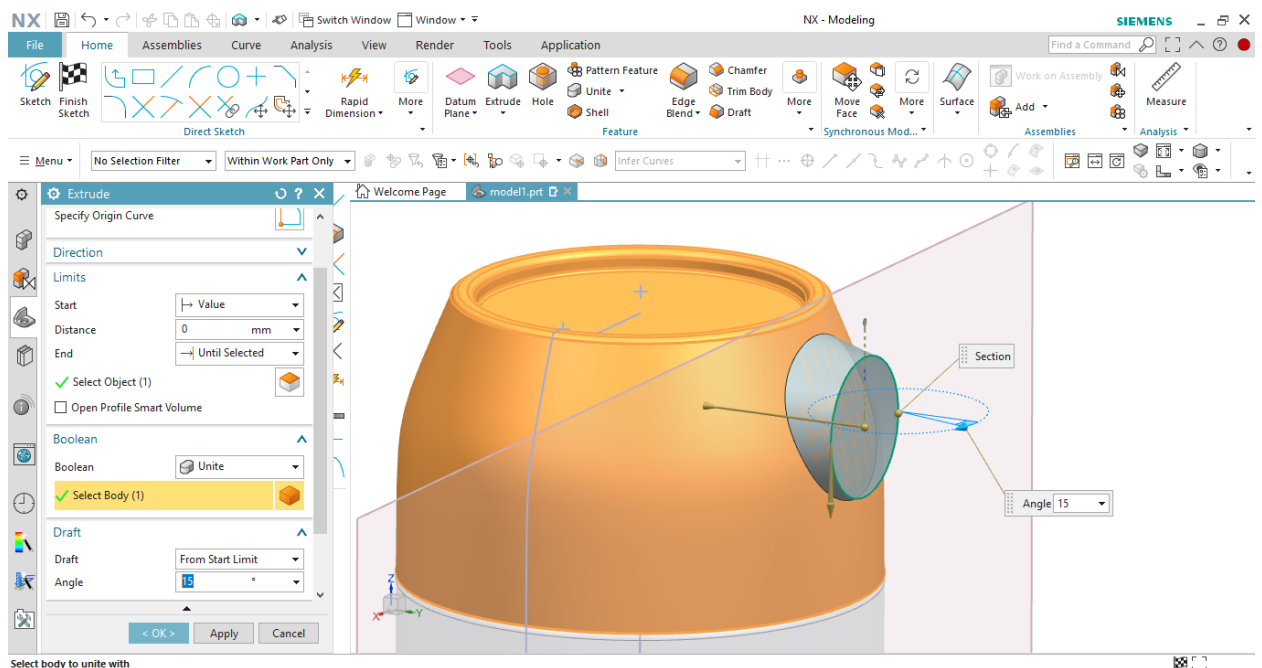


Figure 4.10 – Extrude operation

Extrude operation is a fundamental process for converting 2D sketches into three-dimensional shapes. This operation involves extending a 2D profile along a specified direction to create a solid or surface in the third dimension.

Key Features of the Extrude Operation:

- Profile Definition: Users begin by defining a 2D profile within a sketch. This profile serves as the basis for the extrusion, determining the cross-sectional shape of the resulting 3D object;
- Direction Specification: The extrusion operation requires users to specify the direction in which the profile will be extended to create the 3D geometry. This can be along a linear path or a user-defined vector;
- Depth or Distance: Designers can define the depth or distance of the extrusion, determining how far the profile will be extended along the specified direction. This parameter influences the overall size and volume of the extruded feature;
- Cut or Add Material: The Extrude operation can be used to add material to an existing 3D object, creating a protrusion or solid feature. Alternatively, it can cut material from an existing object, generating voids or cavities within the model;
- Multi-Profile Extrusions: In some cases, multiple profiles can be used in a single extrusion operation. This is particularly useful for creating complex shapes with varying cross-sections.

The Mirror Feature command in the NX is a tool designed for duplicating and reflecting specific features or geometry in a model. This command enables users to create a mirrored version of selected features across a defined plane, simplifying the modeling process and ensuring symmetry or pattern replication. Here are the key aspects of the Mirror Feature command.

The primary function of the Mirror Feature command is to replicate selected features, which can include faces, bodies, or entire components.

Users can specify a mirroring plane or datum plane about which the selected features will be mirrored. This plane serves as the axis of symmetry. The command allows users to mirror multiple features simultaneously, providing efficiency when duplicating complex geometries. In addition to mirroring within a single part or

component, the Mirror Feature command supports mirroring across different assemblies, enhancing its utility in assembly-level modeling.

The mirrored features remain associative to the original ones, meaning that changes made to the original features will be automatically reflected in their mirrored counterparts.

Users have flexibility in choosing mirroring options, such as mirroring about a face, mirroring bodies, or using a user-defined plane for the mirroring operation. Post-mirroring, users can edit and adjust the mirrored features independently, allowing for further customization and refinement.

The Mirror Feature command is valuable for creating symmetric designs, reducing modeling time, and maintaining a consistent and coherent geometry in the overall design process within the NX environment.

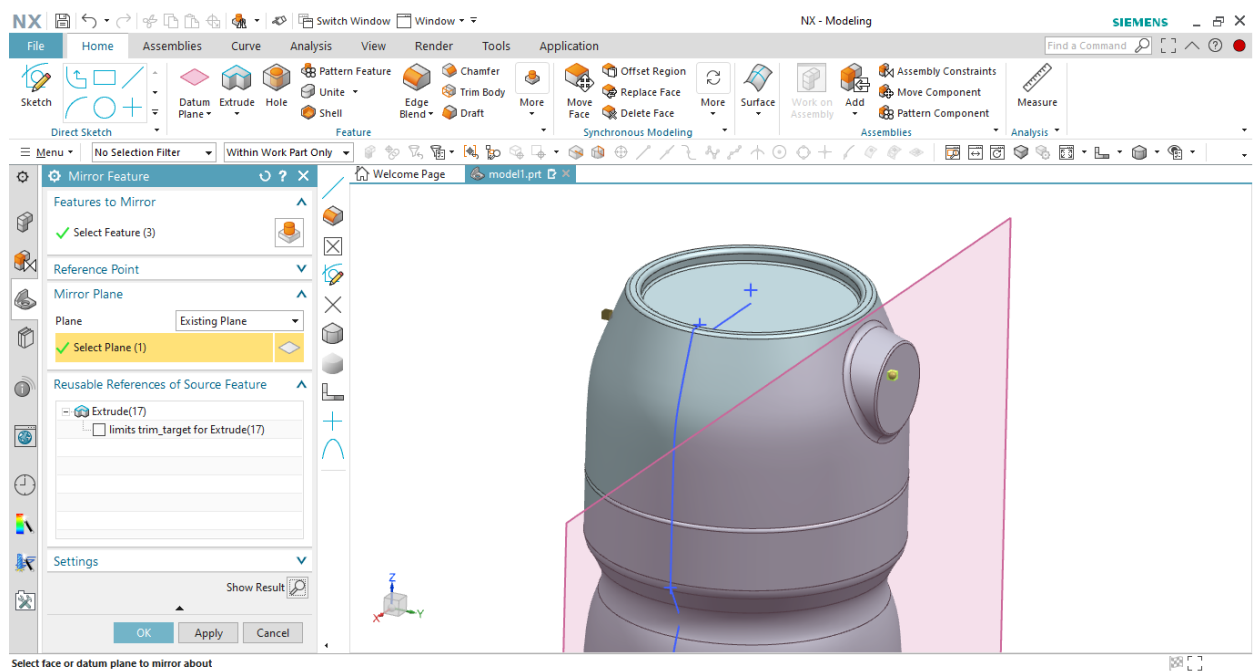


Figure 4.11 – Mirror Feature

Basic operations in NX can be used to add or subtract solids. In the next step of creating a 3D model, we'll use the Extrude operation to create a recess in the water bottle model.

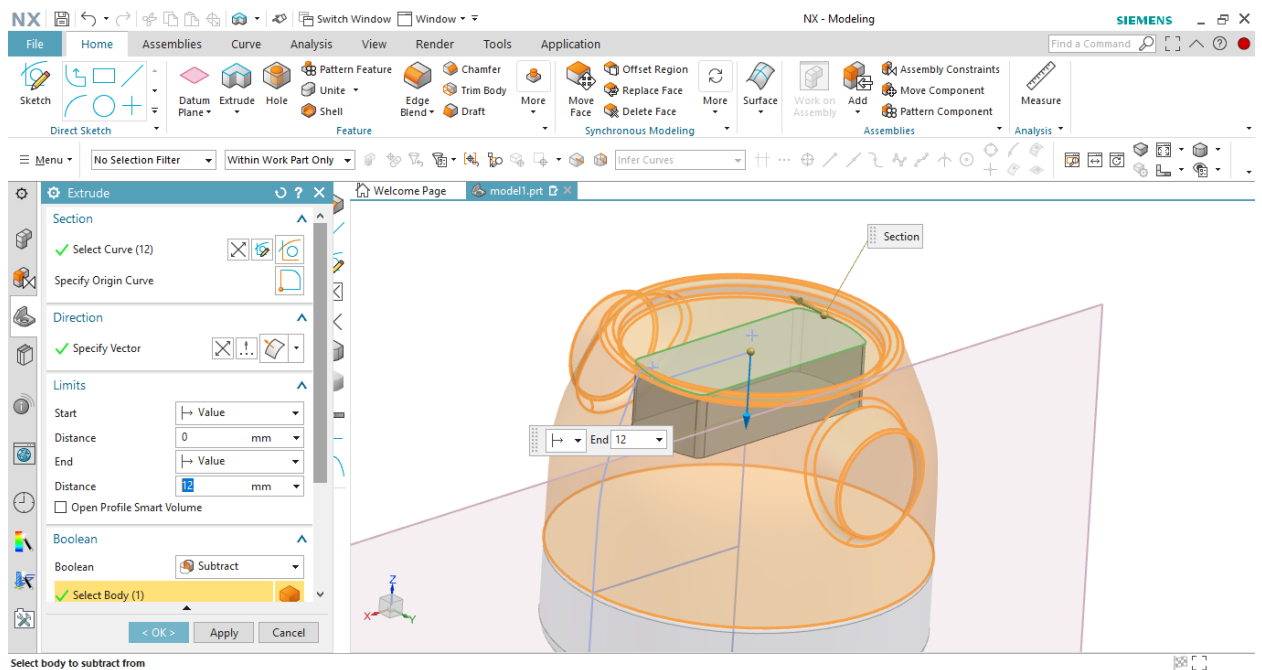


Figure 4.12 – Extrude operation with recess

The following figure shows the built base for the water bottle model.

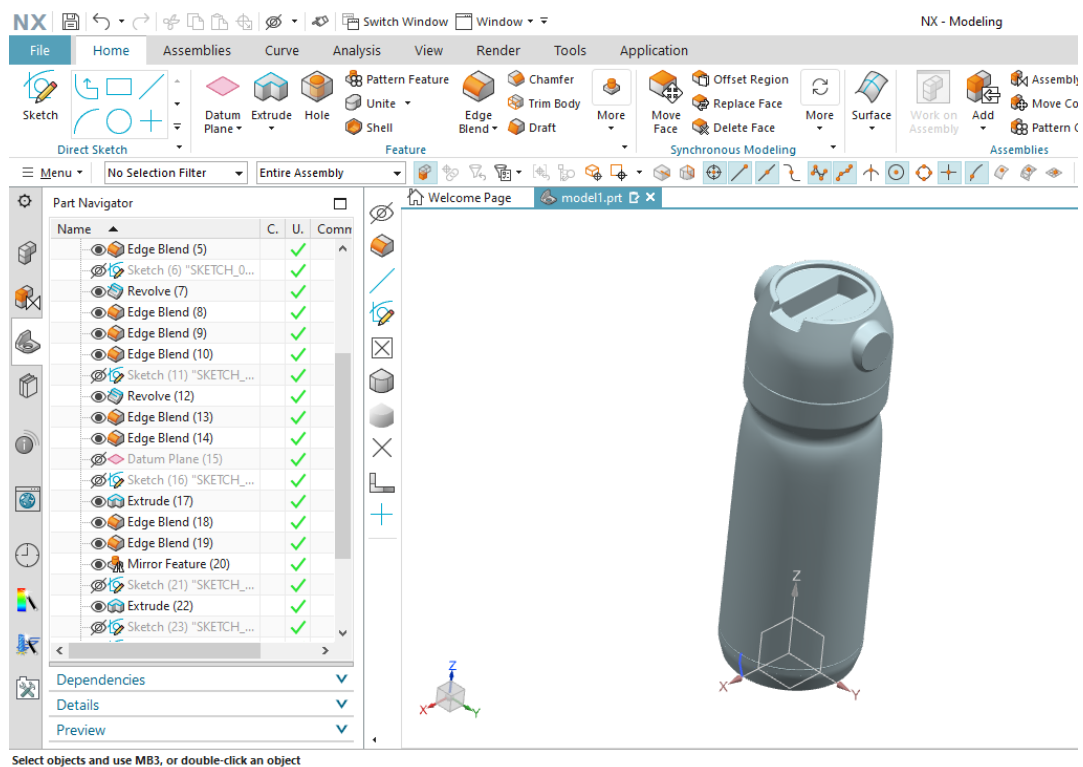


Figure 4.13 – Base for the water bottle model

At the next stage of modeling, we create additional model elements.

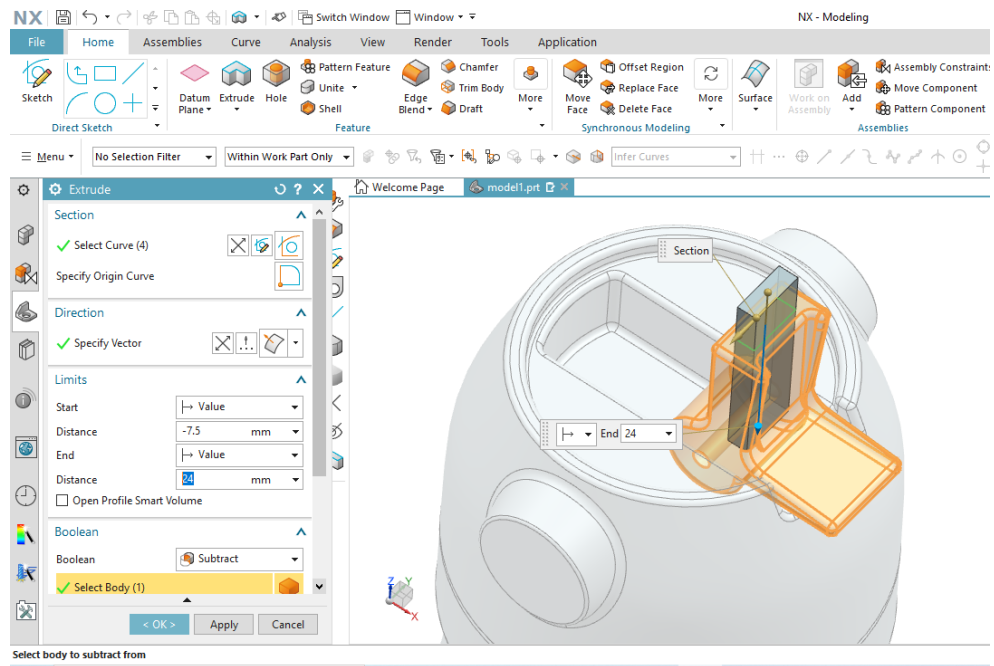


Figure 4.13 – Creation of additional model elements

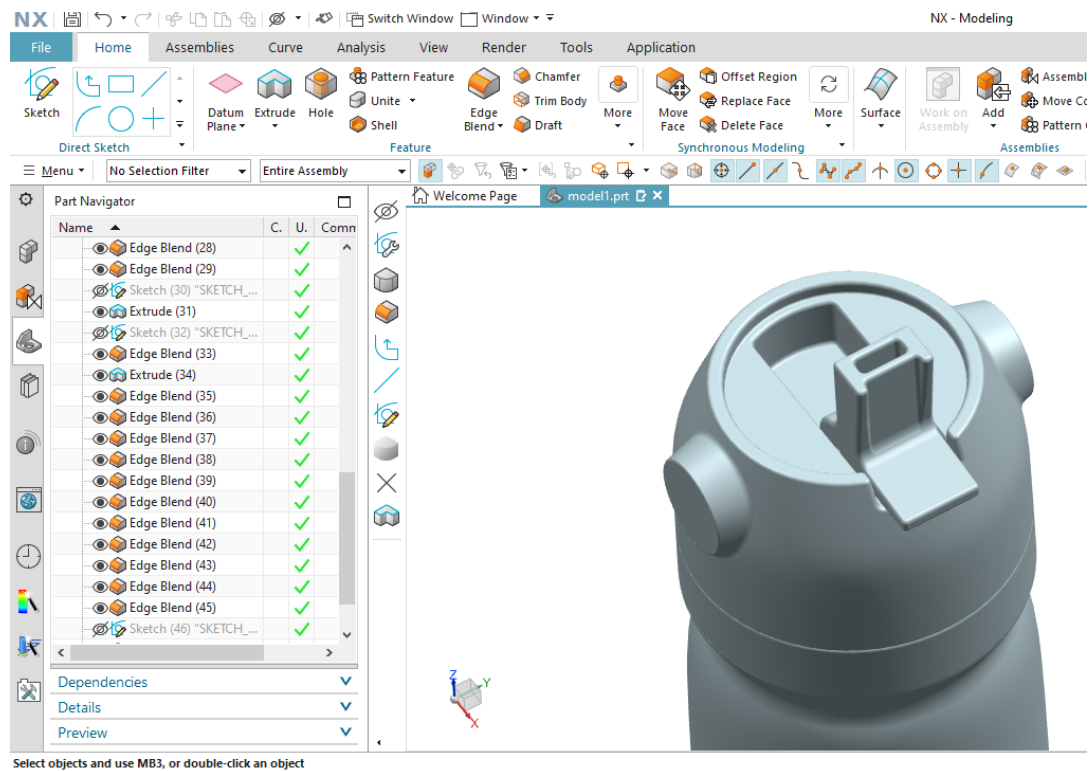


Figure 4.14 – Result of additional model elements

Next, create a handle for the water bottle model.

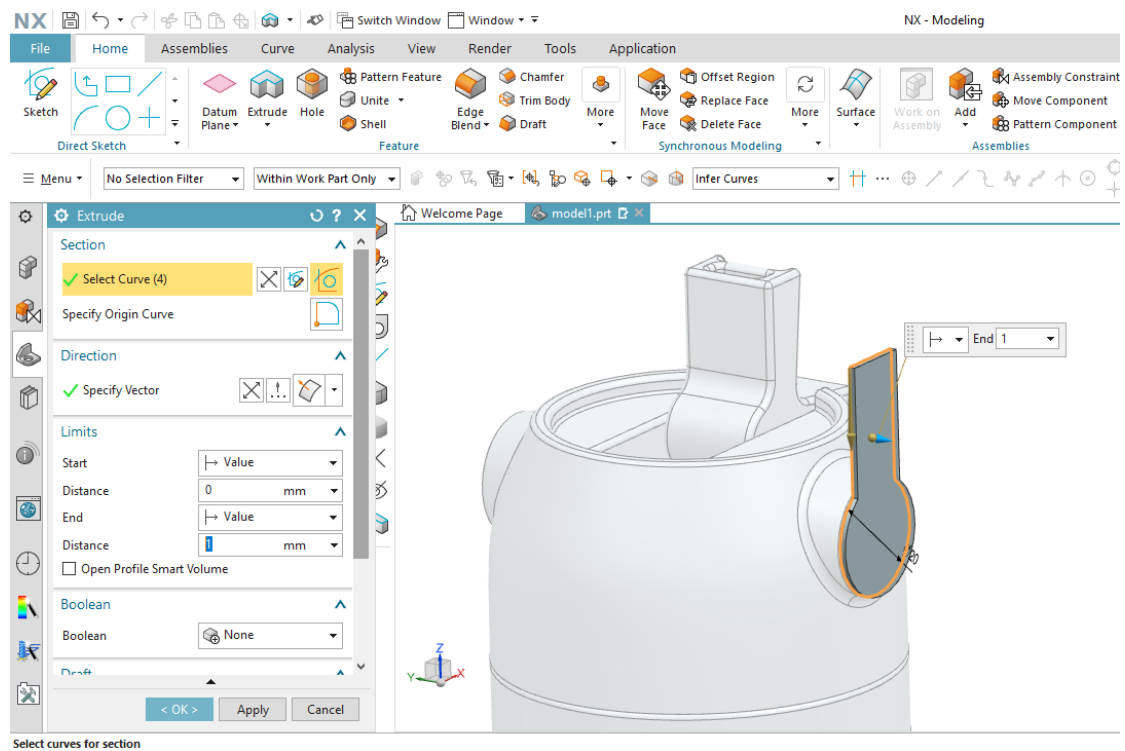


Figure 4.15 – Creation a handle for the water bottle model

The following image shows a finished model of a water bottle. Creating this model required learning a set of NX commands. As a result, we got a model that describes the geometry of the product selected for this work.

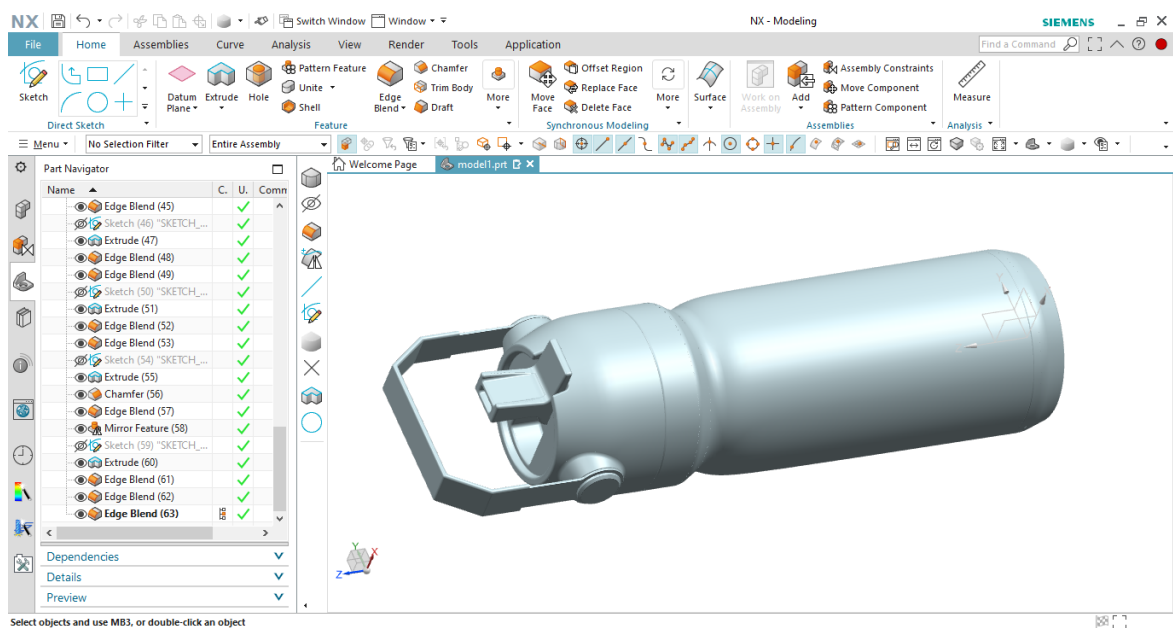


Figure 4.16 – Finished model

Next, for each solid in the model, we assign a different color for display.

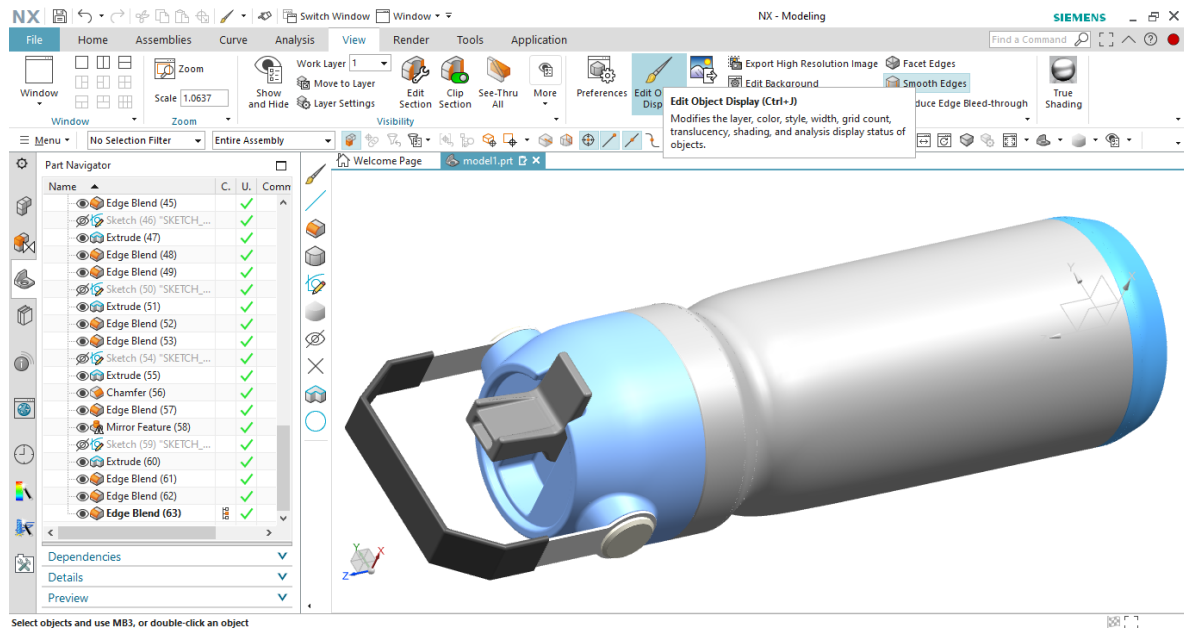


Figure 4.17 – Colors for display each solid in the model

4.2 Setting Up Materials and Textures

At the previous stage, the model was completed, so now we move on to assigning materials and textures. To do this, open the Keyshot 9 program and open the file previously created in NX. That is, the 2 programs are fully compatible in terms of supported file formats.

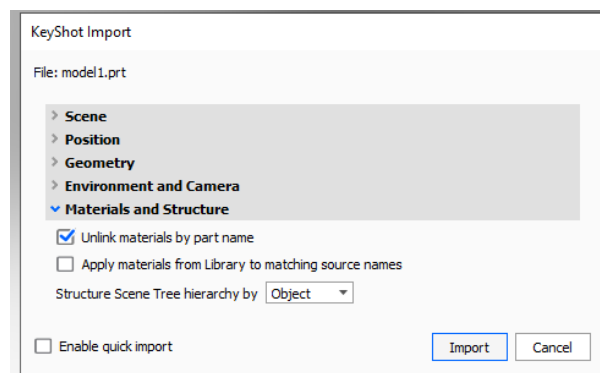


Figure 4.18 – Model import window in Keyshot 9

Keyshot 9 has an extensive built-in material library. Each material has its own texture, color, light, and other characteristics.

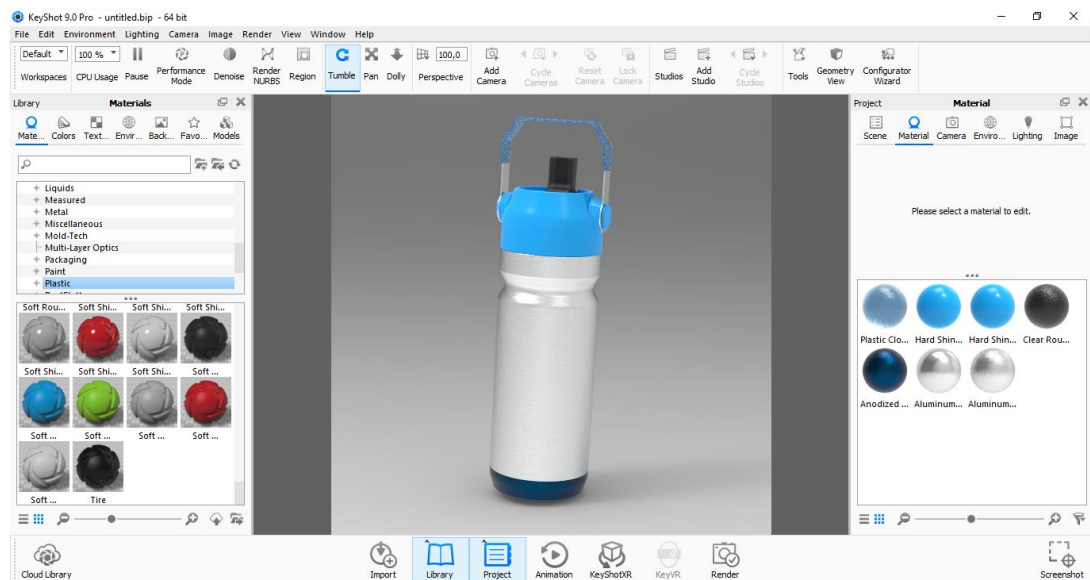


Figure 4.19 – Keyshot 9 visual interface

User can edit the material characteristics. We choose aluminum for the body and handle of the water bottle. For the rest of the parts, we choose plastic.

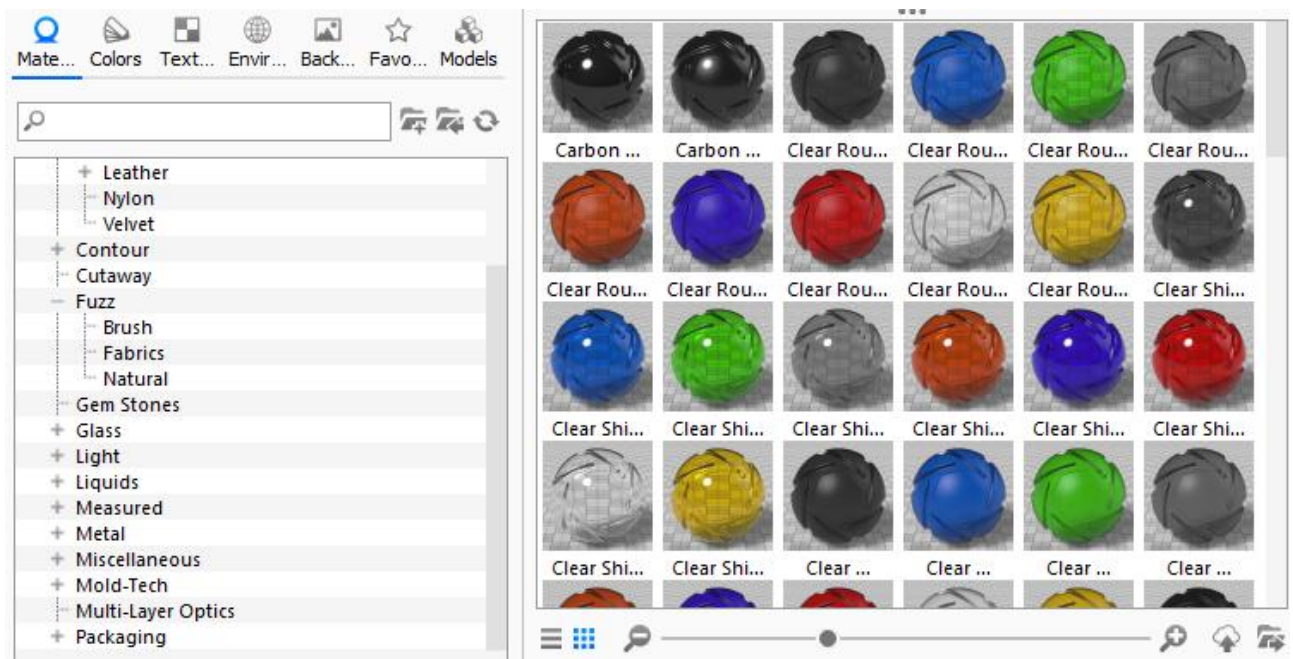


Figure 4.20 – Keyshot 9 materials Menu

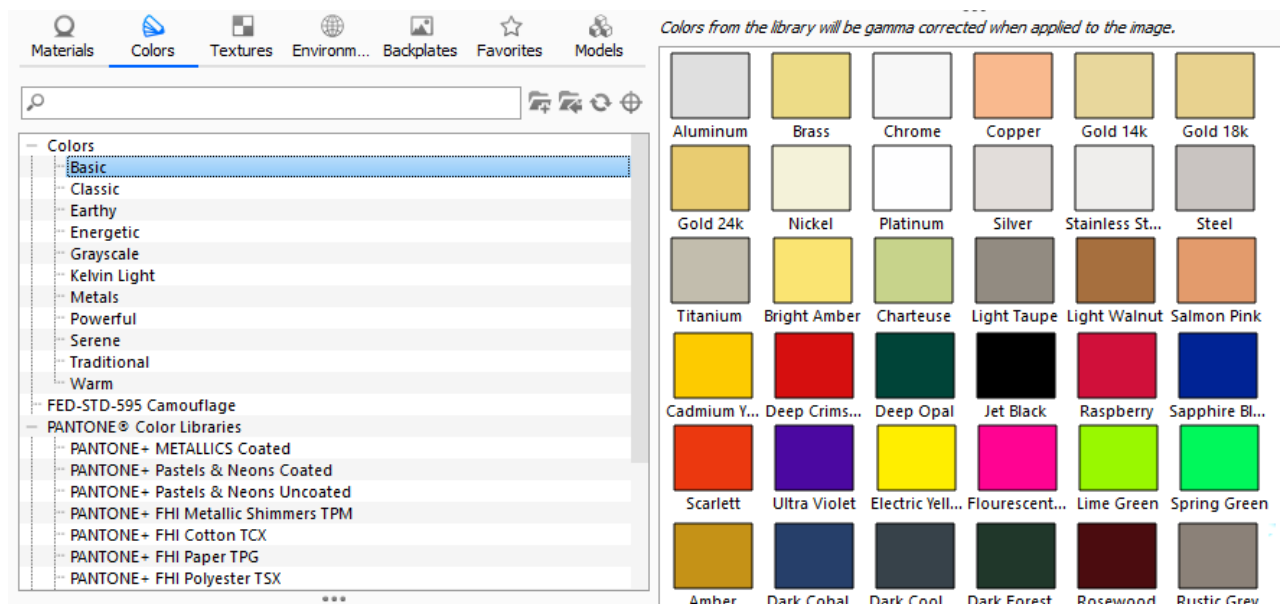


Figure 4.21 – Keyshot 9 colors Menu

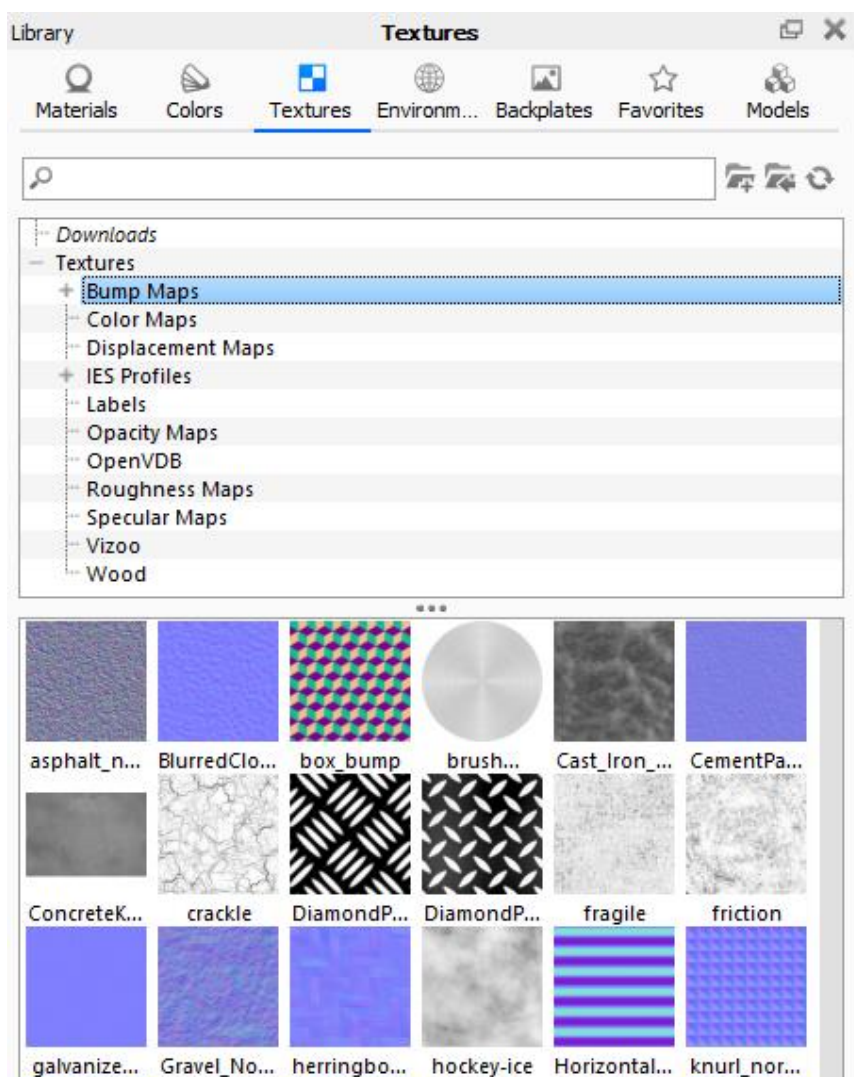


Figure 4.22 – Keyshot 9 textures Menu

Next, let's start setting up the light. To do this, there is a corresponding menu in the program interface. Configure the light and shadow sources. We can choose the geometric location of the light sources, their intensity and type.

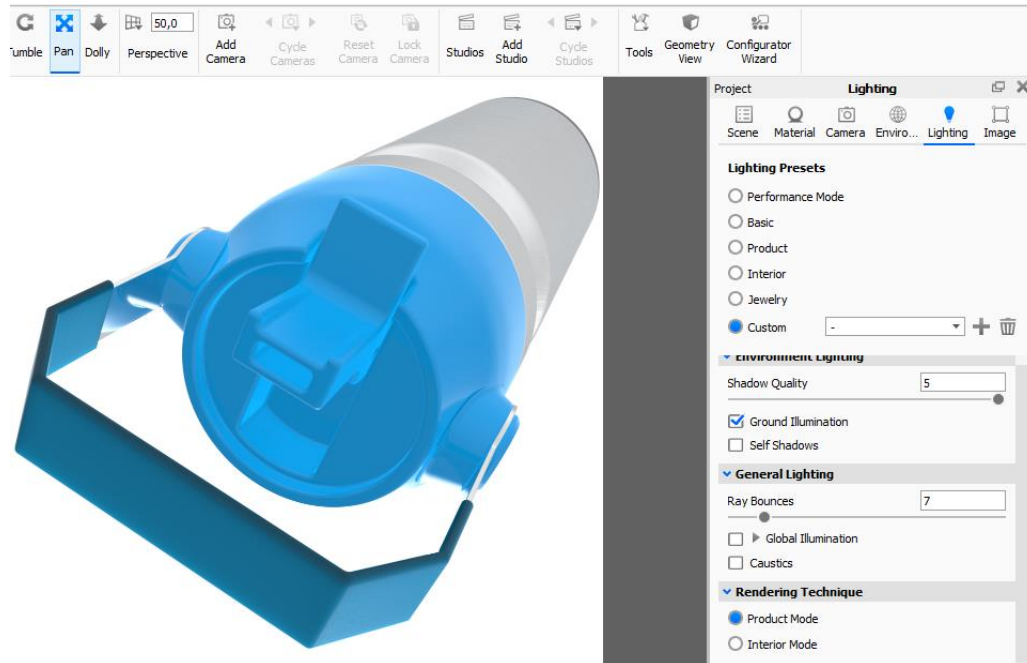


Figure 4.23 – Lighting Settings

4.3 Creation of Visualization

In the context of 3D modeling, visualization refers to the comprehensive process of transforming intricate 3D models into visually compelling and realistic images. The goal is to produce high-quality visual representations that accurately convey the details, textures, lighting, and spatial relationships inherent in the original 3D design.

Visualization involves the application of advanced rendering techniques to generate images that closely emulate real-world lighting conditions. This includes ray tracing, path tracing, and other algorithms that simulate the behavior of light as it interacts with surfaces.

The visualization process meticulously incorporates material properties and textures onto 3D models. This ensures that surfaces exhibit realistic characteristics, such as reflections, specular highlights, and the nuanced details of various materials.

Accurate lighting simulation is fundamental to visualization. It involves positioning virtual light sources, simulating natural and artificial lighting conditions, and considering factors like shadows and global illumination to create visually compelling scenes.

Visualization emphasizes the application of shading techniques to create realistic shadow effects. This includes soft shadows, ambient occlusion, and other shading methods that contribute to the depth and authenticity of the visual representation.

Post-processing techniques are often employed to enhance the final output. This may involve color correction, depth of field effects, and other adjustments to refine the overall visual impact of the image.

Attention to detail in visualization includes ensuring high resolution and image quality. This is crucial for producing images that are suitable for various applications, from digital presentations to print materials.

Visualization carefully considers camera settings and perspectives to capture the 3D scene in a visually engaging manner. This includes selecting optimal angles, focal lengths, and framing to highlight key features of the model.

In the following image, you can see the window with the settings menu before performing the visualization.

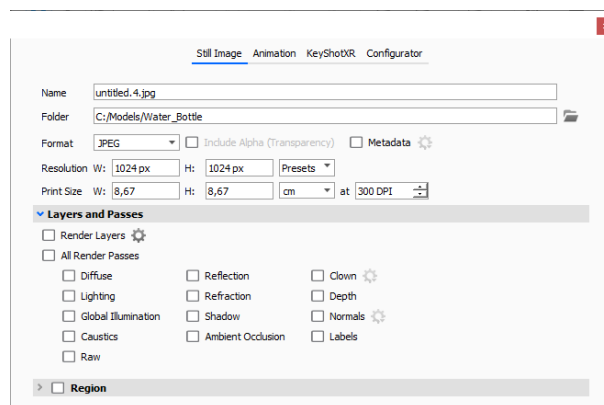


Figure 4.24 – Visualization Settings Menu

The following images shows the visualization results.

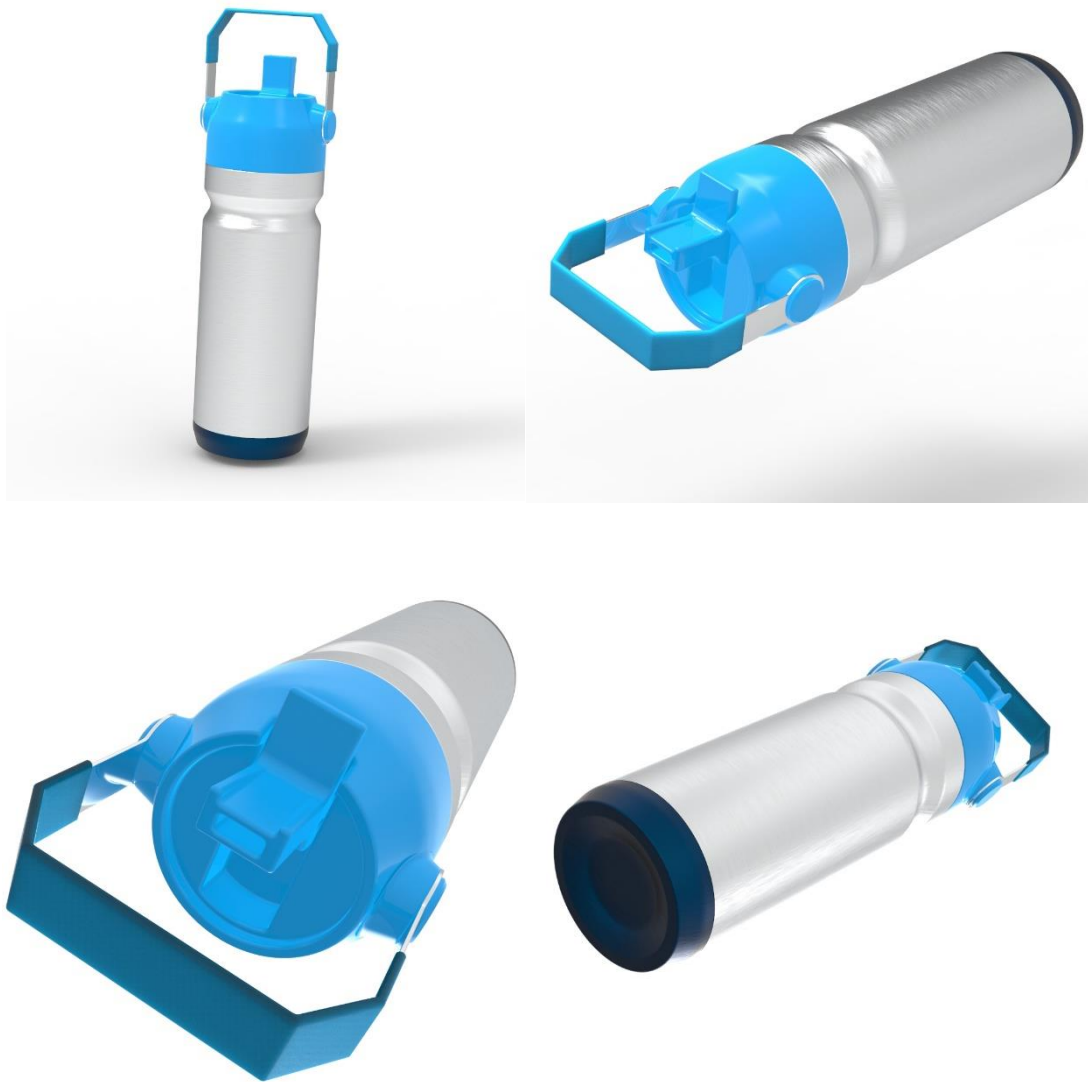


Figure 4.25 – Visualization Results

The ultimate goal of visualization is to achieve realism and aesthetics. High-quality images should not only accurately represent the 3D model but also evoke a sense of visual appeal and artistry.

Visualization benefits from the use of efficient rendering engines that can handle complex calculations and deliver high-quality results in a reasonable amount of time. These engines contribute to the overall efficiency of the visualization process.

The results of visualization find applications in diverse industries, including architecture, product design, gaming, film production, and more. Each industry may have specific visualization requirements tailored to its unique needs.

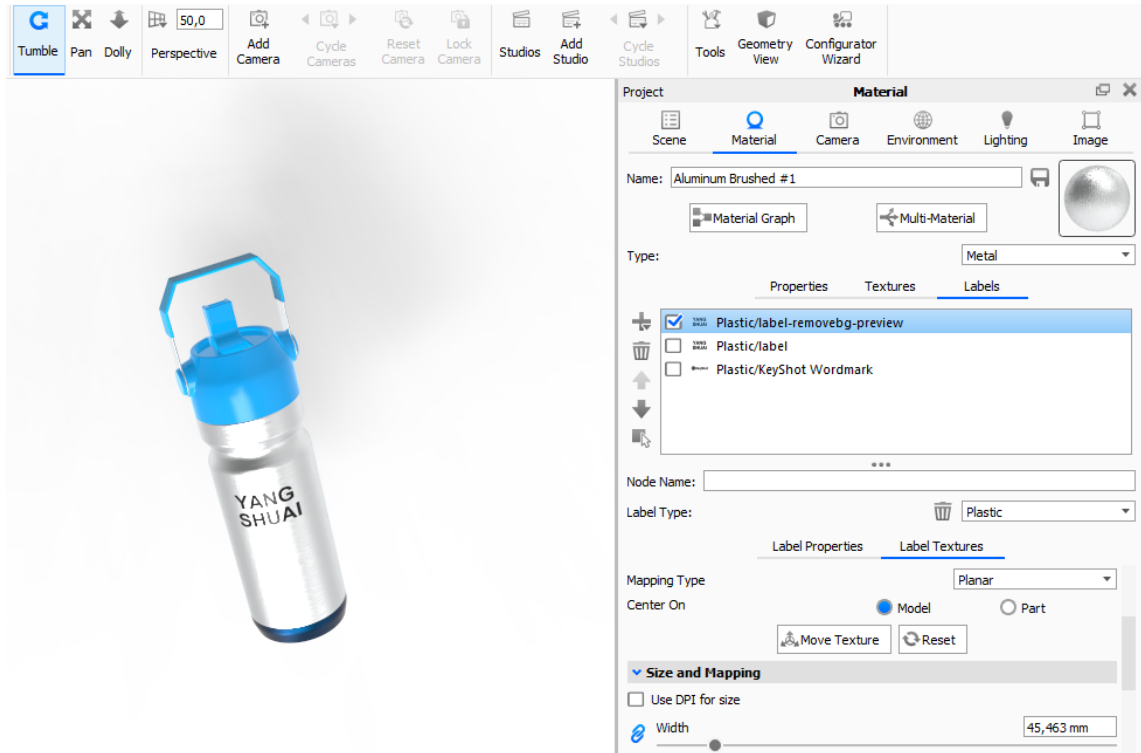


Figure 4.26 – Insert Label to the Model

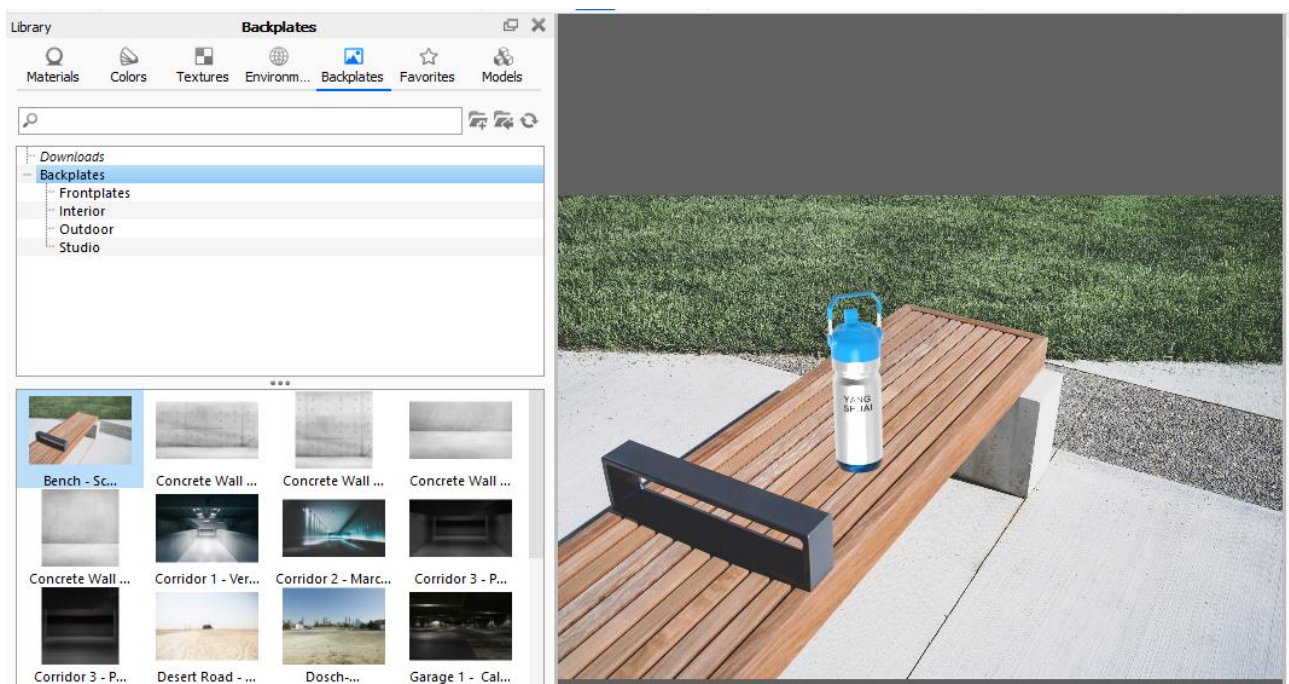
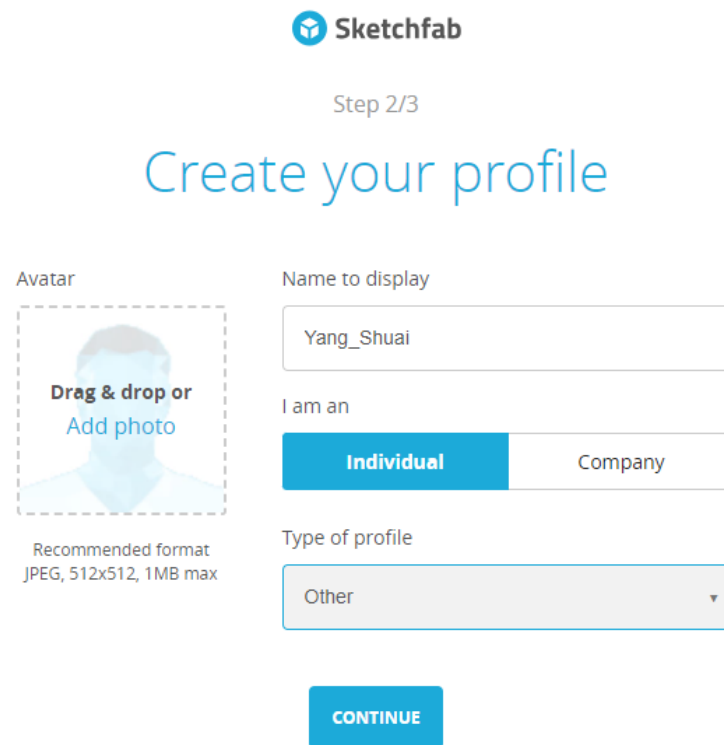


Figure 4.27 – Insert Background to the Model

4.4 Developed Model Publication on the website

I used the Sketchfab platform to publish the 3D model I created. Sketchfab is an online platform designed for uploading, viewing, and sharing 3D models. Users can explore and interact with 3D models directly within their web browsers.

Users have the ability to upload their 3D models to the platform and engage with other members of the community. Models can be viewed in 3D directly on the website. This enables users to explore details and perspectives, and it supports modes such as Virtual Reality (VR) and Augmented Reality (AR).



The image shows the Sketchfab registration interface. At the top is the Sketchfab logo. Below it, the text "Step 2/3" is displayed. The main heading is "Create your profile". The form is divided into two columns. The left column is for the "Avatar", featuring a dashed box with a placeholder image and the text "Drag & drop or Add photo". Below this, it specifies the "Recommended format: JPEG, 512x512, 1MB max". The right column contains a "Name to display" text input field with the value "Yang_Shuai". Below that is a section "I am an" with two buttons: "Individual" (which is highlighted in blue) and "Company". Underneath is a "Type of profile" dropdown menu currently set to "Other". At the bottom center of the form is a blue "CONTINUE" button.

Figure 4.28 – Registration menu on the Sketchfab platform

Sketchfab provides the option to embed 3D models on other websites, allowing users to showcase their work within the context of projects or portfolios.

Models can be categorized and tagged, facilitating easy search and organization of content. In addition to free access, Sketchfab offers commercial options for users to explore monetization possibilities for their 3D models.

Sketchfab is widely used by artists, designers, gamers, and various professionals working with 3D content. It serves as a popular resource for sharing, exploring, and collaborating on a diverse range of 3D models.

The following image shows the registration menu on the Sketchfab platform.

The model is available for viewing at the following link:
<https://sketchfab.com/3d-models/water-bottle-38763215dc394d1283ac235d7d6e770d>

It should be noted that to view the model, the user must be registered on this platform.

The following image shows the display of a 3D model of a water bottle in the Sketchfab platform interface.

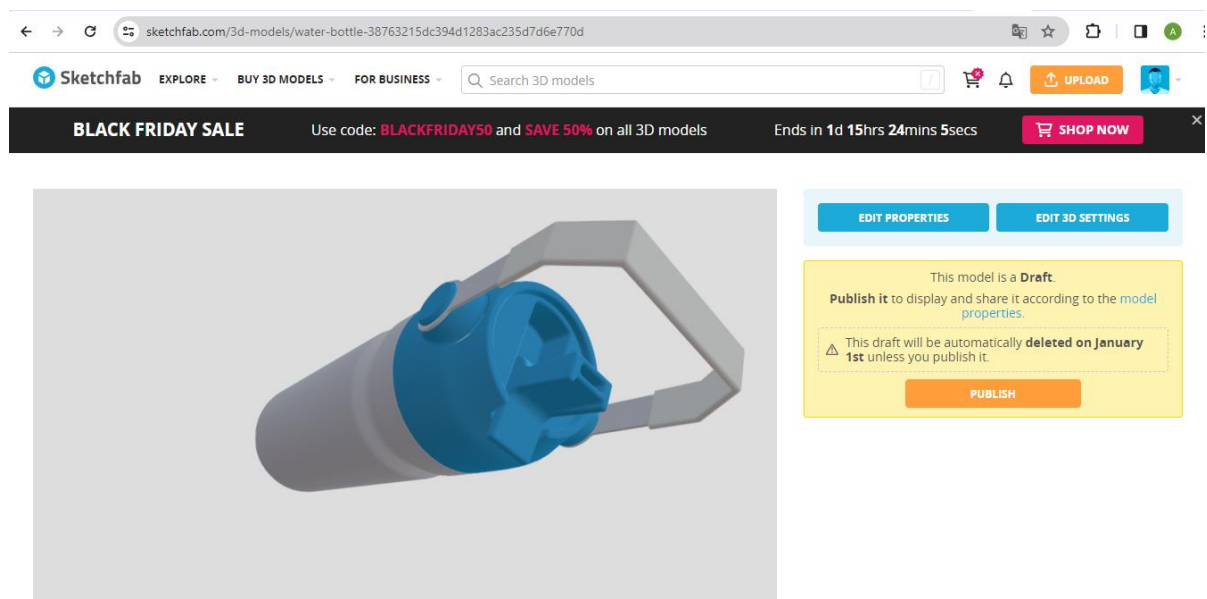


Figure 4.29 – 3D model of a water bottle in the Sketchfab platform interface

In the image below, you can see the presence of a Virtual Reality (VR) mode.

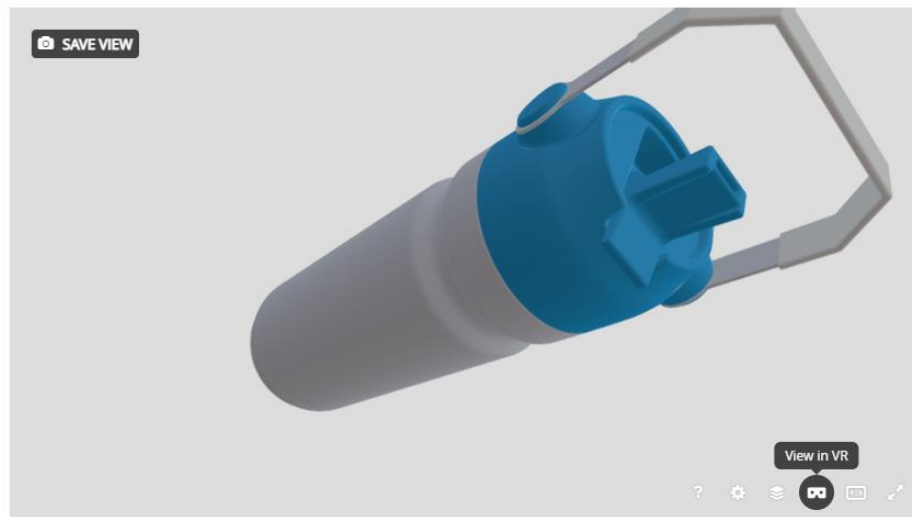


Figure 4.30 – Virtual Reality (VR) mode on the Sketchfab platform

On the Sketchfab platform, the Virtual Reality (VR) mode provides users with the opportunity to interact with 3D content in a virtual environment, creating a more immersive and engaging experience for viewing 3D models. Here are some key aspects of the Virtual Reality mode on Sketchfab:

The VR mode allows users to explore and interact with 3D models in a virtual space. This includes the ability to rotate, scale, and move models using VR controllers or the virtual environment interface. Users can experience 3D models in realistic scenarios, providing a more accurate context and understanding of the sizes and proportions of objects.

Sketchfab supports various VR devices such as Oculus Rift, HTC Vive, and can also work in web browsers, supporting WebVR technologies. Interactivity and Navigation: In VR mode, users can interact with models using controllers or gestures, making navigation and exploration of the virtual space more natural. VR allows users to thoroughly explore models from any angle, providing greater depth and detail during examination. Users can collaboratively view and discuss 3D models in the virtual space, fostering collective and interactive exploration of projects.

The VR mode on Sketchfab adds new dimensions to the perception and interaction with 3D content, making it more accessible and captivating for users worldwide.

CONCLUSION

Virtual reality technology and graphics modeling technology are two important technologies applied in visualization simulation and are hot research areas both domestically and internationally. This paper discusses virtual reality technology and graphics modeling technology and conducts in-depth research and bold attempts on their combined application in system simulation, especially in process industrial system simulation. Finally, a virtual simulation scene display system was developed in combination with the "Graphics Modeling System for Process Dynamic Research". The operating results of the developed system demonstrate the practicality and effectiveness of the combined application of virtual reality technology and graphics modeling technology in system simulation.

In the research process of this topic, the following work has been done:

Analyzed in depth the applicability and limitations of virtual reality technology applied in system simulation. Simulation and virtual reality have a relationship between purpose and expression means. Applying virtual reality, a new form of human-machine interaction, to the display of simulation models can enhance users' perceptual understanding and sense of immersion in the simulation environment. However, virtual reality has the limitation of being easily "lost", and therefore is not suitable for use in the process industrial simulation and modeling process.

Developed a graphics modeling system for process simulation modeling stage. Graphics modeling technology is one of the core technologies of visual simulation. The author has developed the "Graphics Modeling System for Process Dynamic Research", which provides users with a fully functional and easy-to-use graphical modeling environment and various graphics modeling tools. Users can use the various graphic elements provided by the system to build or import device icons; can perform rendering, scaling, rotation, mirroring, and hierarchical adjustment on graphic objects; can import external images; and can connect different device icons with connection lines to

construct the framework of process flow simulation. Currently, the system has been put into practical application.

Throughout the project, I created a 3D model of a reusable water bottle using the NX software. Utilizing NX, I developed a detailed representation of the bottle, considering its shape and functional characteristics. Subsequently, employing the Keyshot program, I translated this model into a visual representation, ensuring realistic lighting and materials.

The final step involved publishing this 3D model on the Sketchfab platform. There, it became accessible for viewing and interactive exploration by visitors. This process not only showcased my skills in 3D modeling and visualization but also allowed me to present the outcomes of my work to a broad audience.

The collaborative sharing of the 3D model through the Sketchfab platform provides an opportunity for other users to interact with the product, closely examining its design and functionality. This project underscores the importance of integrating various software tools for the complete development and presentation cycle of a product—from modeling to visualization and publication.

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