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Exploration of 3D objects: methods for simulation, application, and presentation

Marek Kliment
Technical University of Košice, Faculty of Mechanical Engineering, Department of Industrial and Digital Engineering, Park Komenského 9, 04200, Košice, Slovak Republic, EU, marek.kliment@tuke.sk (corresponding author)

Laura Lachvajderova
Technical University of Košice, Faculty of Mechanical Engineering, Department of Business Management and Environmental Engineering, Park Komenského 5, 04200, Košice, Slovak Republic, EU, laura.lachvajderova@tuke.sk

Tomas Svantner
Technical University of Košice, Faculty of Mechanical Engineering, Department of Industrial and Digital Engineering, Park Komenského 9, 04200, Košice, Slovak Republic, EU, tomas.svantner@tuke.sk

Matus Matiscsak
Technical University of Košice, Faculty of Mechanical Engineering, Department of Industrial and Digital Engineering, Park Komenského 9, 04200, Košice, Slovak Republic, EU, matus.matiscsak@tuke.sk

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Abstract: Simulation programs have revolutionized the operations of major corporations in the 21st century. These programs offer meticulous recording and analysis of processes, enabling the identification and resolution of bottlenecks, deficiencies, and errors that could arise during real-world production. Simulations provide comprehensive insights into the entire production process, even before it begins, ensuring optimal efficiency and minimizing downtime and mistakes. They can be customized to varying levels of complexity, encompassing process-oriented perspectives and visually detailed representations. To ensure accuracy, analyzing and evaluating available data is crucial, supplementing it with necessary information to enhance the virtual representation's fidelity. In this discussion, we will primarily explore the modeling of 3D objects within detailed simulations and their subsequent application and interpretation in diverse contexts.

1 Introduction

The modeling of 3D objects and the methods of their application and presentation have gained significant importance in both simulation environments and beyond. In this era of advanced technology, the ability to create accurate and realistic 3D models has opened up a world of possibilities for various industries. From engineering and manufacturing to entertainment and architecture, the utilization of 3D objects has become a fundamental aspect of visualizing and analyzing complex systems and designs. Within the realm of simulation, the modeling of 3D objects allows for a comprehensive understanding of processes and facilitates the identification of potential issues or optimization opportunities. Simulation software, such as Tecnomatix Plant Simulation, provides a platform for integrating these models seamlessly into virtual environments, enabling the exploration and fine-tuning of production processes with enhanced accuracy and efficiency [1].

However, the application and presentation of 3D models extend far beyond the boundaries of simulation. These models find applications in product design, virtual prototyping, architectural visualization, and even immersive experiences like virtual reality. They serve as powerful tools for communicating ideas, showcasing concepts, and facilitating informed decision-making.

This study focuses on exploring the utilization of 3D visualization and the integration of models within the Tecnomatix Plant Simulation software. Additionally, it examines the application and presentation of these models in diverse contexts beyond the simulation environment. The software provides a comprehensive library of predefined models, encompassing basic representations of machinery, conveyor belts, and various types of transportation vehicles. Users have the flexibility to customize the graphics of these objects within the simulation, allowing for visual modifications according to their specific requirements [2].

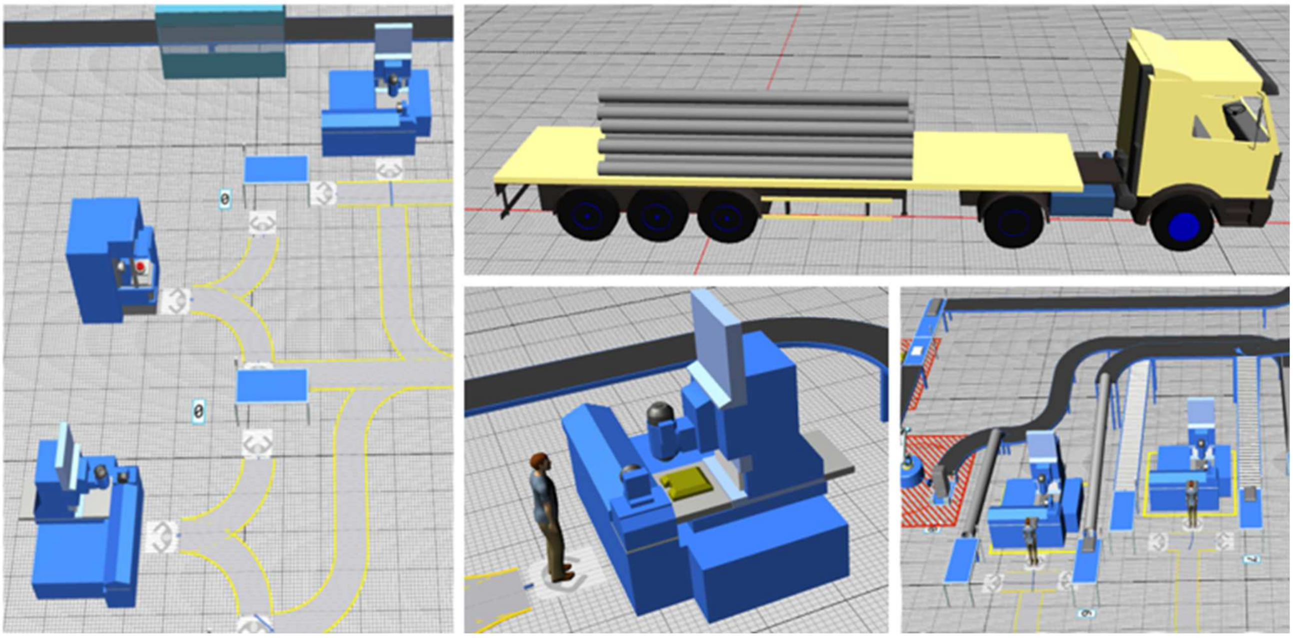

Figure 1 3D objects available in the TX Plant Simulation library

2 Development of 3D model

In addition to modifying the graphical representation of simulation objects using the software's default graphics, there is also the option to connect with CAD software. This connection is essential for obtaining precise dimensions and specifications of individual devices or components in most simulations. Consequently, it involves the complete processing of these elements using CAD software. However, the integration between simulation and CAD software is not direct and seamless. For this particular simulation, we employed SolidWorks CAD software, developed by Dassault Systèmes SolidWorks Corporation. As the production process focused on creating a bearing puller (refer to Figure 2), each individual part underwent distortion and was subsequently exported in a compatible file format, allowing it to be readable within the simulation software and integrated into the overall simulation setup [3]. Prior to the actual distortion of parts within the software, this process was preceded by creating detailed drawing documentation. SolidWorks CAD software also offers the option to generate digital forms of drawing documentation as one of its output possibilities.

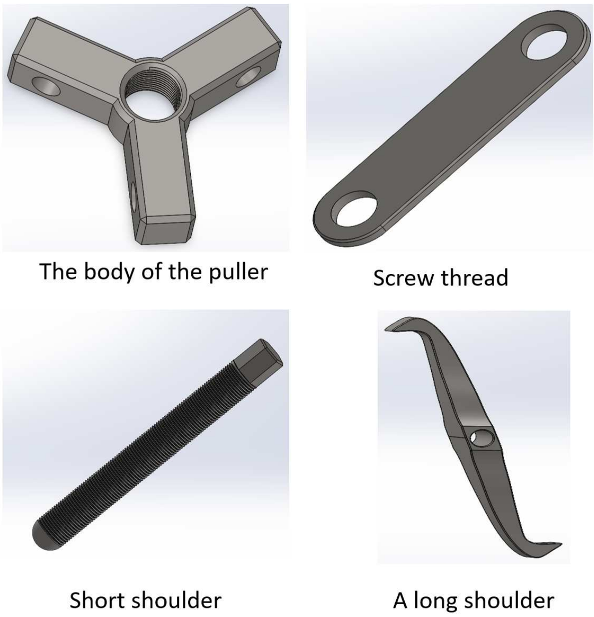

Figure 2 Components of the Puller Body

The puller body represents the foundational structure of the entire part, making it the initial focus of production as discussed and optimized in the previous chapter. As the core component, it is the first element to be incorporated into the assembly process. The second part involves attaching a screw to the central hole of the body using an internal thread. This screw applies pressure to the bearing that requires disassembly. Careful design ensures that the screw does not damage the surface of the part being manipulated. It features a hexagonal head, allowing for the use of a ring or open-end wrench. Six short arms are attached to the puller body at the assembly site using specialized production equipment. These short arms facilitate movement and overall adjustment of the long arms based on the size of the component being manipulated. The long arm, which is the final part, undergoes assembly just prior to packaging and shipping. Due to its complex shape, the long arm is designed using casting technology. In the simulation, this component is considered a purchased item delivered directly to the assembly site. To simulate the functionality of all parts and identify any potential errors, CAD software is employed to assist in the assembly process. Standardized components like nuts, bolts, and washers are incorporated into the assembly, adhering to ISO standards during the design phase. SolidWorks CAD software provides access to a library of these standardized parts. To ensure comprehensive project documentation, the software also offers the option to create drawing documentation for the entire assembly. It is worth mentioning that the exact material specifications are defined, allowing for the calculation of the total weight of the manufactured part.

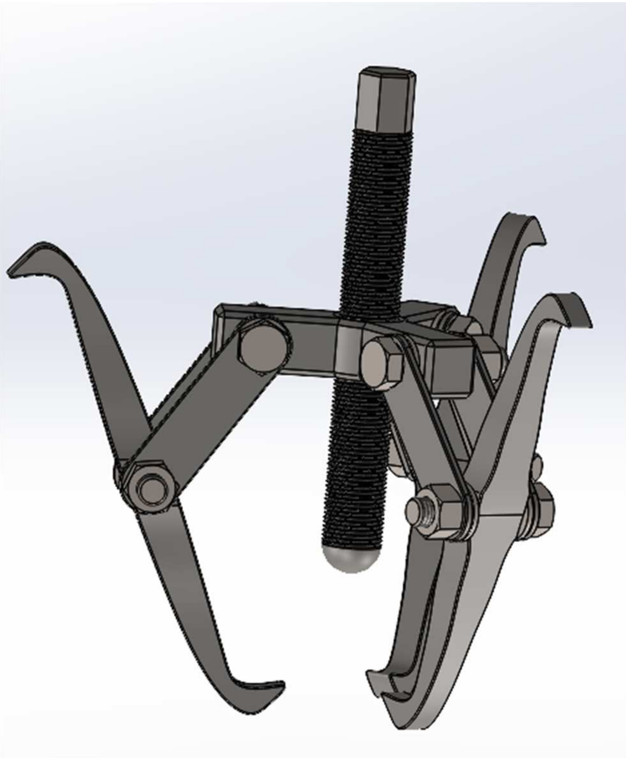

Figure 3 Assembly - The Puller

2.1 Integration of 3D objects into the Plant Simulation environment

The distorted 3D models created using CAD software can be seamlessly integrated into the simulation as part of the material flow. This process is similar to inserting objects from the default library of the simulation software. Within the CAD software, the specific model is exported in the form of a STEP file, which ensures convenient conversion to other file formats. To facilitate compatibility with the simulation, the exported file is then converted to the JT file format using a readily available online converter [4].

The JT file format is essential for the successful integration of the 3D models into the simulation. This format allows for efficient data transfer and ensures that the models can be accurately represented within the simulation environment. By converting the file to JT format, the necessary compatibility is established, enabling smooth and seamless integration of the distorted 3D models into the simulation workflow.

This streamlined process of converting and importing the CAD-distorted models ensures that the simulation accurately reflects the real-world production environment. It allows for the detailed analysis of material flow and enables precise evaluation of production processes. By leveraging readily available tools and file formats, users can effectively utilize their CAD-created models within the simulation, enhancing the overall accuracy and effectiveness of the virtual environment [5].

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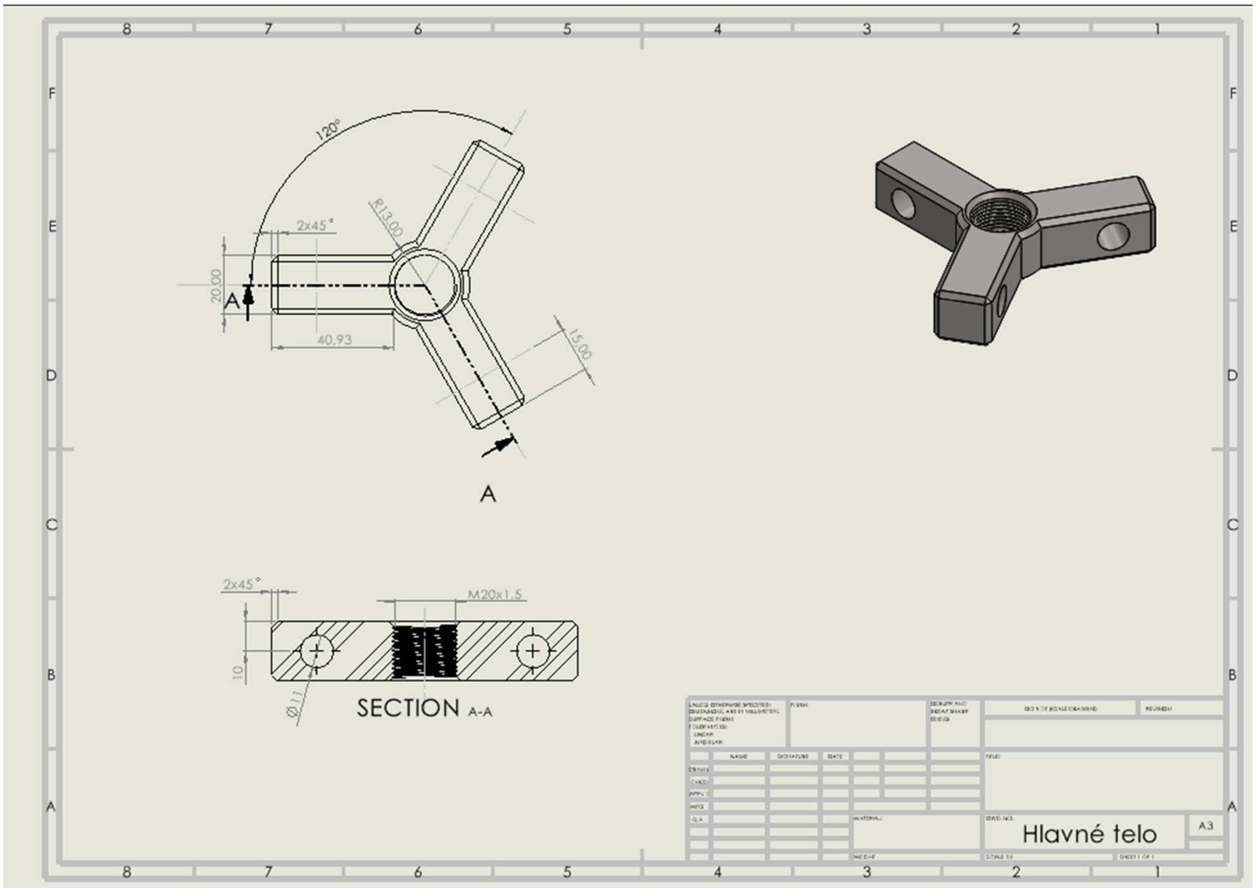
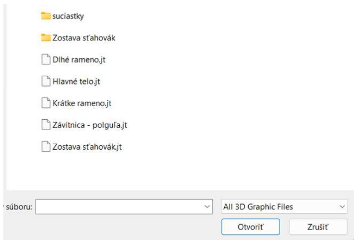
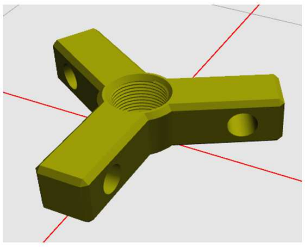


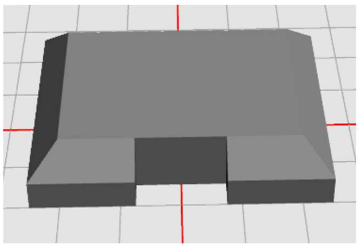
Figure 4 Drawing documentation generated through the utilization of CAD software



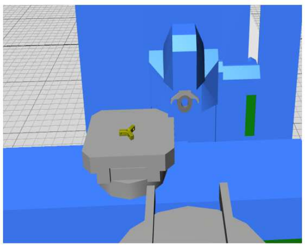
Selection of the converted JT file



Custom graphic display of the puller's body in simulations



Default graphic display of the puller's body in simulations



The puller body clamped at the milling workplace

Figure 5 Incorporating models into the simulation environment

The integration of distorted 3D models created in CAD software into the simulation is a straightforward process. Similar to inserting objects from the simulation software's default library, these models become part of the material flow. The CAD software exports the models as STEP files, which can be easily converted to other formats. Converting the exported files to the JT format is crucial for seamless integration into the simulation environment. The JT format ensures efficient data transfer and accurate representation of the models within the simulation. This streamlined process enables a faithful reflection of the real-world production environment, allowing for detailed material flow analysis and precise evaluation of production processes. Leveraging available tools and file formats empowers users to effectively utilize their CAD models, enhancing the overall accuracy and effectiveness of the virtual environment.

2.2 Output and presentation options for the simulated production process

Virtual reality (VR) can be effectively employed as a means of representing the simulated production process, serving various purposes in the realm of training and immersive experiences. This widely recognized technology is frequently utilized in training operators who operate specific assembly equipment, offering a realistic and hands-on learning environment. The integration of VR with the simulation process further enhances the overall experience and effectiveness of the training.

By incorporating VR technology into the simulation, users can delve into a virtual world that closely replicates the production environment. They can explore and interact with the simulated equipment, machinery, and processes in a highly immersive manner. This realistic representation facilitates a deeper understanding of the production workflow and enables operators to gain practical experience in a safe and controlled setting [6].

The use of VR in conjunction with the simulation allows for a more comprehensive and engaging training experience. Operators can practice and refine their skills, familiarize themselves with equipment functionalities, and develop efficient strategies for handling various production scenarios. This immersive approach helps operators build confidence, improve decision-making abilities, and enhance overall performance. Moreover, VR technology provides the opportunity for collaborative training and remote learning. Multiple users can participate simultaneously in the virtual environment, regardless of their physical location. This feature enables effective teamwork, knowledge sharing, and the exchange of best practices among operators and trainees.

Figure 6 VR resources and tools

The Steam application serves as a bridge for facilitating communication between the simulated manufacturing process and the Oculus application. It acts as a mediator, enabling seamless interaction and data exchange between the two systems. The Steam app plays a crucial role in establishing a connection between the simulation software and the Oculus app, ensuring that the virtual reality experience is effectively synchronized with the simulated manufacturing environment. It handles the transmission of information, commands, and feedback, allowing for real-time interactions and accurate representation of the production process within the virtual reality setting.

The integration of virtual reality into the simulated production process brings numerous benefits. It offers a representative and immersive experience, particularly for training operators. By leveraging VR technology, operators can develop practical skills, enhance decision-making capabilities, and foster collaboration in a safe and controlled virtual environment [7].

2.3 3D printing

3D printing technology offers another valuable tool for visualizing the production process and manufactured parts. This technology serves multiple purposes, including confirming precise dimensions and representing the final outcome of the production process. By utilizing additive manufacturing techniques, such as 3D printing, practitioners can create physical prototypes that accurately reflect the intended design. This process enables a tangible representation of the part, allowing for a thorough examination of its dimensions and features. Through 3D printing, the intricate details of the part can be realized, providing a realistic representation of the final product.

3D printing technology plays a crucial role in showcasing the entire production process. By printing individual components or assemblies, stakeholders can physically observe the progressive stages of production and gain a deeper understanding of the overall manufacturing workflow [8].

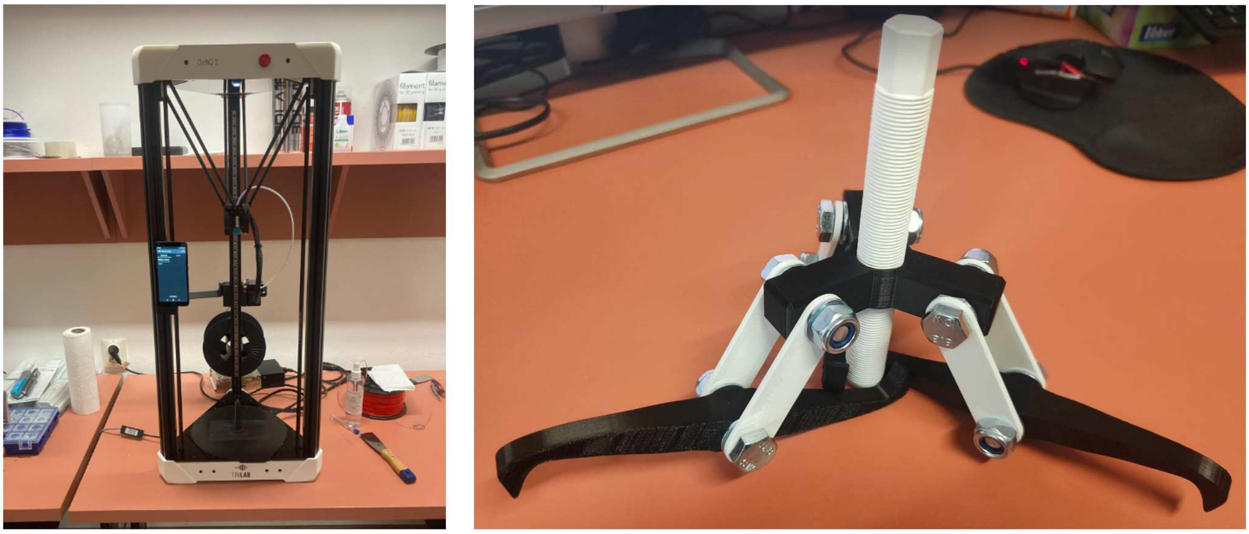


Figure 7 3D printing of a bearing puller

The utilization of 3D printing technology serves as a practical solution in this context, aiding in the confirmation of dimensions and providing a tangible representation of the production process. It enables practitioners to validate designs, assess functionality, and identify potential areas for improvement. By leveraging the benefits of 3D printing, stakeholders can enhance their visualization capabilities and make informed decisions throughout the production journey.

3 The application of holographic imaging in simulated production

In addition to their applications in simulation, 3D printing, and virtual reality, holographic projectors offer an alternative method to visualize and present created models. Unlike conventional two-dimensional images captured by cameras or video cameras, holographic projections provide a spatial representation that goes beyond the flatness of traditional images.While techniques like those used in 3D cinema can create the illusion of depth, they lack true spatial characteristics such as parallax. Parallax refers to the variation in the position of different points within an image when viewed from different angles. In contrast, holographic projections offer a more immersive experience by allowing viewers to observe scenes from different perspectives and even glimpse objects from behind. True holographic methods are based on specific conditions and specialized tools. The fundamental process involves directing a laser at a semi-transparent mirror, which splits the light into two beams. One beam interacts with the object being recorded, while the other reflects off another mirror. The two beams eventually intersect on a photographic film, creating an interference pattern that forms the hologram.

Conventional images captured by cameras or video cameras are limited to a two-dimensional representation. This means that they lack the ability to convey depth and spatial information, as they are interpreted and displayed on a flat surface, such as a desktop. While there are techniques, such as those used in 3D cinema, that attempt to overcome the flatness of a two-dimensional image, they are not truly spatial in nature. Although they can create the illusion of depth by making certain parts of the image appear closer than others, they lack a crucial element known as parallax. Parallax refers to the positional difference of two distinct points within an image when viewed from different angles. In a typical 3D cinema experience, even if you were to move several seats to the right or left, you would still perceive the same image without any change in perspective. However, if the image were a hologram, you would observe the scene from a slightly different viewpoint, allowing you to partially see behind displayed objects. Holograms possess the unique characteristic of providing a more immersive and dynamic viewing experience. They enable viewers to perceive the entire scene from different angles, creating a sense of depth and allowing glimpses of hidden details. Unlike traditional images, holograms offer a more realistic representation of three-dimensional space and enhance the overall visual engagement and interactivity for viewers.

A true hologram is a holographic image captured from two different perspectives, resulting in a visual experience where each viewpoint offers a slightly different perception, resembling a real scene. While there are various techniques and illusions that mimic three-dimensionality, genuine holographic methods are limited and require specific conditions and specialized tools for their creation. To simplify the process, a laser is directed at a semi-transparent mirror, splitting the light into two beams. One beam illuminates the object and is reflected, while the other beam reflects off another mirror. Eventually, the two beams intersect on a photographic film, generating an interference pattern that forms the hologram [9].

However, this process solely captures the hologram on the film. To display the hologram, a similar illumination technique is employed, recreating the original recording conditions. However, it's important to note that current holographic technology is not yet capable of capturing and reproducing moving objects with convincingly sharp and smooth results. As a result, alternative technologies are used to create spatial images, even though they have limitations and cannot produce true holograms. Nevertheless, these techniques can create compelling illusions that are often sufficient for various applications.

Rotating holographic projector

One common method used to create a holographic-like effect is through the use of a rotating projector. This "holographic projector" typically consists of rotating arms with RGB diodes attached. As the arms spin rapidly, the LEDs emit flashes of light. The rotation speed is carefully synchronized with the blinking of the LEDs, making sure that the colors are always displayed in specific positions within the circular "display area." The resulting effect gives the impression of a transparent image floating in space. However, it's important to note that this approach lacks true spatiality. The movement of the "holographic fan" arms only creates a surface, resulting in a two-dimensional image. Consequently, these fans do not generate actual holograms but rather transparent two-dimensional images.

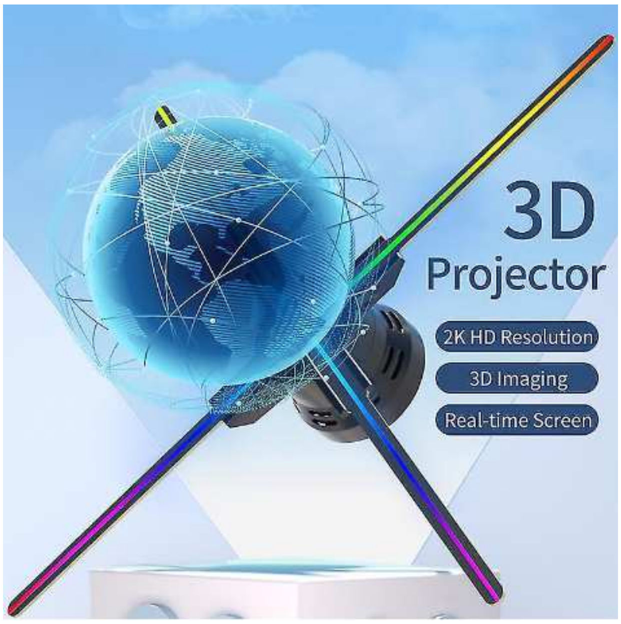


Figure 8 Rotating holographic projector

This type of projector utilizes rotating arms equipped with RGB diodes. As the arms rotate, the diodes emit flashes of light. The rotation speed is precisely synchronized with the diode blinking, ensuring that the colors appear in specific positions within the circular "display area." This creates the illusion of a transparent image suspended in space. However, it is important to note that this setup does not produce genuine holograms but rather two-dimensional images with a sense of depth. The rotation of the arms creates a surface-like effect, limiting the projection to a flat plane instead of true three-dimensional representation [10].

4 Conclusions

The simulation aspect of the project aims to enhance the visualization of the production process for improved efficiency. By leveraging the capabilities of simulation software and combining various inputs and outputs, it becomes possible to design and comprehend proposed changes in the manufacturing process more effectively. Integrating custom 3D objects into the simulation creates a digital twin, allowing for a realistic representation of a production line, which is particularly advantageous considering the limited library of machines and their components in the Tecnomatix Plant Simulation program.

The practical part of the study focuses on the integration of custom 3D objects, designed using Solidworks modeling software, with the simulation. This section covers the creation of custom objects, the documentation of these objects, and their subsequent conversion into the required file format for seamless integration with the simulation. Moreover, these models can be utilized for 3D printing, enabling the physical production of objects, or showcased on various holographic projectors to visualize and present them in an immersive manner.

Overall, this research explores the potential of combining simulation, custom 3D modeling, 3D printing, and holographic projection to enhance the understanding and implementation of manufacturing process improvements.

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