

DEVELOPMENT AND APPLICATION OF A GLASSES-FREE 3D DISPLAY SYSTEM BASED ON A PSEUDO-HOLOGRAPHIC PYRAMID

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This article presents a study on the design and implementation of an affordable, glasses-free 3D visualization system utilizing a pseudo-holographic pyramid. It outlines the technology's working principles, presents a practical implementation case, and discusses its potential applications in education. The results confirm the effectiveness of this approach for creating engaging 3D illusions without specialized hardware.

Keywords: reflective optics, Pepper's Ghost illusion, prototype development, educational tools, 3D modelling, visual demonstration.

The continuous evolution of digital display technologies has increased demand for immersive visual experiences that require no specialized user equipment. Recent studies highlight that glasses-free stereoscopic displays are gaining traction in various professional and educational fields [1]. Glasses-free three-dimensional (3D) visualization represents a significant step forward in making digital content more accessible and intuitive to interact with. Research confirms that students find such three-dimensional tools engaging and effective for understanding complex structures, which supports the growing interest in implementing these technologies in educational settings [2]. This study explores a low-cost solution based on established optical principles to create compelling 3D content. Such visualizations can improve learning comprehension, attract audience attention, and serve as effective demonstration tools. The primary goal of this work is to develop and validate a functional pseudo-holographic display system. To accomplish this, three main tasks were undertaken. First, a comparative analysis of contemporary glasses-free 3D visualization techniques was conducted. Second, original 3D digital content was created and prepared through modelling, texturing, and animation specifically optimized for pyramid projection. Finally, this digital content was integrated

with the existing pyramid structure to evaluate the system's perceptual effectiveness.

Modern technologies for creating 3D images without glasses can be broadly categorized into systems that generate pseudo-3D optical illusions and those that produce true volumetric or holographic images [3].

Pseudo-3D illusion systems are among the most historically significant and widely accessible. The foundation of this category is the Pepper's Ghost illusion, which operates on a simple principle where a high-contrast image from a hidden source reflects onto a transparent surface placed at a 45-degree angle to the viewer. This optical arrangement creates a semi-transparent, ghost-like object integrated into physical space. The technique's advantages include simplicity, low cost, and strong visual impact, explaining its enduring popularity in theatres, museums, and educational exhibits [4]. However, its main limitation is the inability to reconstruct a true light field, offering only monocular depth cues [3].

An evolution of this concept is the Holographic Pyramid Display, which expands the Pepper's Ghost principle into a multi-faceted format. Typically configured as a four-sided transparent pyramid, it uses a single horizontal screen beneath the structure. A specially formatted video

with four synchronized views of a 3D object plays on the screen, with each pyramid face reflecting one view to create a composite image that appears as a solid 3D model floating inside. As viewers move around the display, they see different object sides, significantly enhancing the spatial presence and depth illusion compared to basic Pepper's Ghost setups [3]. Modern implementations use advanced digital rendering for realistic animated sequences, increasing system interactivity and appeal [3, 4].

The practical implementation involved creating a working prototype beginning with digital reconstruction of the "Bonch Tigers" SPbSUT mascot. Using ZBrush, a high-resolution digital sculpture was developed, then created a low-polygon version through retopology for smooth performance. Texturing in Substance Painter

produced essential material maps including Albedo for base color, Roughness for surface glossiness, and Normal for simulating detailed surfaces. These maps ensured realistic material response under the pyramid's reflective conditions. Then a seamless 360-degree rotation in Blender was established, rendering the scene with Cycles path-tracing at Full HD resolution and 30 frames per second. HDRI lighting simulated natural environmental lighting for authentic reflections. The process yielded four video sequences showing the rotating tiger from cardinal directions. Using a 3-mm transparent acrylic pyramid selected for optical clarity, the videos were composited into a cross-pattern ensuring perfect synchronization. When played on a horizontal tablet, the system produced a striking illusion of a colorful, animated 3D tiger floating within the pyramid (Fig. 1).



Fig. 1. The operational pseudo-holographic pyramid displaying the animated "Bonch Tigers" mascot

System testing under different lighting conditions confirmed that dim environments produced the most vivid, high-contrast illusions, while strong overhead lighting caused some image fading, consistent with known limitations of reflection-based systems [3]. User feedback from

demonstrations was overwhelmingly positive, with observers noting strong depth perception and expressing surprise at the effect's clarity and stability from various viewing angles.

To sum up, the successful implementation of this pseudo-holographic pyramid

system validates its utility as a powerful yet accessible tool for 3D visualization. The project demonstrates a complete pipeline from asset creation to integration, showing that impressive results require modest resources. The system's key advantages are accessibility and reproducibility, with low material costs and open-source software like Blender making it feasible for educational institutions and small businesses. Applications are diverse, including visualizing historical artifacts,

molecular structures, and anatomical models in education, where it may promote more consistent learning outcomes [5], alongside product prototype showcases in corporate settings and engaging interactive exhibits in museums and galleries [3, 4]. In the future, improvements will include system scaling and added interactivity through motion sensors for user control. This work provides a foundation for developing affordable immersive technologies.

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РАЗРАБОТКА И ПРИМЕНЕНИЕ СИСТЕМЫ АВТОСТЕРЕОСКОПИЧЕСКОЙ 3D-ВИЗУАЛИЗАЦИИ НА ОСНОВЕ ПСЕВДОГОЛОГРАФИЧЕСКОЙ ПИРАМИДЫ

Н. И. Щедрин

Статья представлена научным руководителем – ст. преп., Маршева Н. В.

Данная статья представляет исследование по разработке и реализации доступной системы 3D-визуализации без использования очков на основе псевдоголографической пирамиды. В работе описываются принципы работы технологии, представлен практический пример реализации и обсуждаются потенциальные возможности применения в об-

разовании. Результаты подтверждают эффективность данного подхода для создания 3D-иллюзий без специализированного оборудования.

Ключевые слова: рефлексивная оптика, иллюзия «призрак Пешпера», разработка прототипа, образовательные инструменты, 3D-моделирование, визуальная демонстрация.

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