

Research Article

OPACITY INFLUENCED INCONSTANT METHOD FOR 3D HOLOGRAPHIC PYRAMID RENDERING

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Abstract

The rapid growth of computer graphics in human daily life has inspired researchers to maximize image understanding and discover new methods for visualizing 3D objects. However, the image quality is constrained by the depth cue limitations of 3D objects produced by 3D displays. The advent of the holographic hologram pyramid display offers better image quality due to its ability to visualize 3D data with satisfactory depth. In this paper, we present a new visualization method named the "opacity influenced inconstant method" that exploits the custom surface rendering technique to enhance understanding of massive 3D objects for a hologram pyramid display. An algorithm is developed by adding an opacity variable and manipulating the intensity and position of the other variables to enhance the depth cues of a 3D object. The opacity value has the ability to show the inner structure of an object to be visualized if it is available. Our results show significant enhancement on the depth cues of the 3D object that presents as a hologram floating inside a transparent pyramid. The results of a survey conducted on computer graphics students shows that the quality of the hologram was preferred when it was compared to the previous method. In addition, the depth cues of the 3D object were reported to be enhanced by the opacity influenced inconstant method when compared to the previous and standard studies.

Keywords: 3D visualization, depth cue, Phong shading, 3D holographic display, surface Rendering.

الخلاصة

ان التطور السريع في مجال رسوم الحاسوب في حياتنا اليومية اعطى الحافز للكثير من الباحثين لتوضيح وزيادة دقة الصور الرقمية وكذلك الاشكال ثلاثية الابعاد. بالرغم من ذلك، فان جودة الصور محددة بعدة عوامل منها العمق او البعد الثالث للصورة المعروضة على الشاشة ثلاثية الابعاد. ان اختراع الهرم الهولوكرافي (هرم شفاف) ممكن ان يوفر دقة اكبر للصور وذلك لقابليته على اعطاء احساس بعمق الصورة او بعدها الثالث. في هذه الدراسة، قمنا بتطوير تقنية تم تسميتها "طريقة متغير الشفافية" وذلك من خلال تعديل تقنية مسح الصور السطحية لتحسين شكل وبعد الشكل الثلاثي الابعاد. تم تطوير خوارزمية بواسطه اضافة متغير الشفافية والتلاعب في شدة وموقع المتغيرات الاخرى في هذه الخوارزمية لتحسين عمق وتفاصيل الشكل الثلاثي الابعاد. متغير الشفافية له القابليه على اظهار المكونات الداخليه للشكل الثلاثي الابعاد في حالة توفرها. نتائج الدراسة اعطت تحسن كبير في عمق الصورة الطافية على شكل هولوكرام معروض في الهرم الشفاف. تم اجراء استطلاع للرأي على طلبة رسوم الحاسوب وبعد تحليل النتائج وجد ان جودة الهولوكرام بالطريقة التي تم استخدامها في الدراسة كانت اكبر من جودة الصور بالطريقة السابقة. بالاضافة الى ان عمق الشكل ثلاثي الابعاد تم تحسينه باستخدام طريقة متغير الشفافية عند مقارنتها بالدراسات السابقة.

Introduction

The depth cues are the ability of the humans to perceive depth in sensed images. These cues classified to monocular cues (3D information from a single eye) and binocular cues (3D

information from two eyes). The human visual system interprets depth information in a sensed image by using all the available cues automatically [1]. Numerous researchers proposed methods to improve the rendering quality by applying shadows, illumination, and



transparency like [2] who proposed various types of directional lights to enhance visual perception of 3D data.

The human brain uses four major physical depth cues to gain true 3D sensation. The first, accommodation, is the process of changing the eye's lens shape by the eye muscles when focused on an image of a 3D object in a scene. The second, convergence, is the measurement of the distance that the eyes have to cross to see a 3D object concurrently. The third, motion parallax, compares the relative motions of different elements in a 3D scene to offer depth cues. And finally, binocular disparity is the differences in images acquired by the left and right eyes.

The traditional 2D display devices can show only flat images that lack the third dimension (depth information). However, the physical world around us is three-dimensional. The flat images limit the human ability to perceive and to understand the complexity of real-world objects. Various technologies for visualizing a 3D object on displays have been demonstrated and refined such as stereoscopic, autostereoscopic or holographic type. The main conflict of these technologies is providing all the depth cues that the human eyes can observe to show an object with natural properties [3].

According to the review that was conducted on the previous studies on 3D display technology, stereoscopic displays have controversy with accommodation and convergence cues but can afford binocular parallax only [4]. It limits the number of views of horizontal parallax only or two views. In addition, these types of displays need additional equipment to be viewed such as special glasses. Autostereoscopic displays can gain 3D perception without the need for such equipment but they reduce 3D resolution [5, 6]. Moreover, Autostereoscopic displays shear distortion and limit the relief depth range but can acquire the best depth with the stereoscopic cues [7]. However, holographic displays offer the opportunity for users to perceive 3D images in natural depth perception and are considered as the next generation of 3D display technology. Holographic displays

provide all depth cues that human eyes can observe and support full parallax [8, 9]. The hologram pyramid display can create hologram with worthy depth and its simple, cheap and allows moving the eyes freely without need to wear any kind of viewing device.

In previous work, we have shown that hologram delivered via hologram pyramid display could enhance the shape perception by proposing new lighting position [10]. Rendering for such displays requires an appropriate color, projector, and design to make the hologram appear in the correct position, clear, and understandable. We employed mobile phone and tablet to project our 3D data placed under the hologram pyramid display. Moreover, two different sizes of the pyramid were employed that support four view of the object from different position. Accordingly, the main contributions of this study include:

- Developing a lighting system that manipulates intensities of lights over distance to enhance shape perception and produce proper light for projecting our 3D object on the hologram pyramid.
- Adding transparency to 3D model to enhance the third dimension (depth) cues for our volumetric data.
- Creating four viewports to contain four views of the 3D object from a different angle for hologram pyramid which requires

In this paper, we present a 3D data visualization that enhances the depth cues of 3D data for the viewer of a transparent hologram pyramid display. It is based on the combination of a lighting hologram style, 3D hologram rendering with customized rendering technique named as opacity influenced inconstant method. Recent advances in 3D display design prove that can create hologram with worthy depth and its simple, cheap and allows Multiview moving the eyes freely without need to wear any kind of viewing device [11].

In the following sections, we will discuss the previous solutions to the problem, our proposed solution for the current problem and

its implementation as well as evaluation. It starts with Section 2 which gives an overview of several previous technical elements and algorithms for the previous works of the 3D displays and 3D visualization. Section 3 presents the methodology and the design of our proposed method to enhance the depth cues. Section 4 discusses the experiment, the results and discussion related to the experiment. Finally, we highlight the conclusion and future works from this study in section 5.

Related Work

The following review shows the high impact of the depth cue on human vision, 3D displays and the latest study to enhance the depth cues in the human perspective.

3D display technology:

3D display has rapidly become important in computer graphics, visualization, virtual reality, and computer gaming. The improvements have been in speed, resolution, and economy where earliest technologies have been enhanced, and new ones have been developed. It has developed and become significantly cheap and, produced 3D interaction in real-time [12]. The world around us is three-dimensional whilst traditional display technologies are missing depth information by showing only two-dimensional images (flat images).

The real world is significantly limited by the human's ability to observe and understand the complex objects [8]. Patterson [13] provides recommendations for designing 3D displays and reviews a number of important perceptual factors associated with 3-D viewing. Mikkola, Boev, & Gotchev is studied the relative importance of different depth cues on a portable auto-stereoscopic display with extensive subjective experiments [14]. Cutting & Vishton are reported a quantitative analysis of the effect of different depth cues on human depth perception [15]. The sensitivity of humans for different depth cues is analyzed as applicable to 3-D viewing on stereoscopic displays is investigated by [16].

The depth cues in the human visual perception of 3D displays are discussed the visual comfort and image quality. The analysis is concentrated on near-range depth cues, depth-range capabilities, compared visual performance of stereoscopic and holographic displays, and evaluated the depth limitations of 3D displays. The researchers found, stereoscopic display is limited viewing comfort due to the limitation of non-consistent convergence-accommodation cues and unnatural motion parallax. However, holographic displays could show natural 3D scenes with unlimited depth and consider holography as the preferred option for 3D displays [7]. A review on the advancement of 3D displays (stereoscopic, autostereoscopic, volumetric, and holographic) and grouped them with respect to their ability to reproduce parallax presented by [17]. A state of the art [8] of 3D display technologies is compared various 3D display technologies and evaluated their impact on viewers' depth perception by providing a depth cue comparison. The result from the comparison found that only holographic displays can satisfy the psychological and physiological depth cues. A classification of visual depth cues, 3D display technologies and their applications is presented. The study provides guidelines about the common characteristics of 3D display applications based on constraints, limitations, advantages and costs [18]. In 2015, state of the art of 3D display technologies is categorized 3D display technologies to four categories and discussed their limitation. Computer-generated hologram (CGH) technologies are become a dominant direction in 3D display and measured to be the next generation of 3D display technology [19].

Agus et al. [20] enhanced 3D data and provided real-time visualization on light field displays with unlimited size to generate dynamic observer independence. A new method for creating realistic computer-generated holograms (CGHs) is proposed using a polygon-based method to render specular surfaces. Specular reflection was imitated by a modified spatial spectrum of the imitated light.

The Phong reflection model was utilized to control the shadowy shape of the imitated light. The technique satisfied fast computation to create several specular polygons and was significant for creating high-definition computer generated holograms (CGHs) [21]. Zhang, Zhao, Cao and Jin [22] were presented an algorithm for producing 3D computer-generated holograms (CGHs). The algorithm was proved by using multiple shading effects and optical reconstruction. Phong reflection model employed to simulate the realistic lighting influence and calculate holograms. A phase-only spatial light modulator (SLM) was used in this study to achieve the optical reconstruction. Recently, the algorithm developed for fully computing holographic stereogram to calculate full-parallax (CGHs) and to provide all the depth cues of the three dimensional scene. A precise accommodation cue and occlusion were reconstructed to improve the image fidelity [23].

Nowadays numerous researchers have used Pepper's Ghost technique [24] that has been measured as the most popular technique to produce a holographic illusion and create holograms [25, 26]. It has been used in playhouse, museums and concerts [26]. The technique principle is using special light effects with a plate of glass rotated at a 45 degree angle to the viewer's [27]. The holograms created by this technique gave a sense of depth perception and gave the impression of an object floating in the air without the need for special glasses. However, the holograms that were generated using Pepper's Ghost technique were measured as not true three dimensional displays because of the conceptions of light fields, volumetric, or the reconstruction of light wave fronts using diffractive interference [8].

Three-dimensional visualization

Non-photorealistic rendering (NPR) techniques were employed in computer graphics to mimic painting, or drawing technical illustration. A huge number of researchers were inspired by the capability of NPR to offer various visual appearances and different styles. In 1998, an

incredible works are carried out in the field of NPR and by proposing NPR lighting model for technical illustrations purpose that based on a cool-to-warm shading algorithm [28]. Later, the same group of researchers is advanced shading method to present interactive technical illustrations that influences with lights, and objects movement or viewer's position. Combining their previous study and improved with new shading algorithm produces many illustration techniques that enhanced the shape and depth. Furthermore, it is unsuitable for utilize with changing meshes due to relying on expensive pre-computation [29]. Browning is found that the warm colors enhance the depth cue and the cool color reduces it [30]. Birren is created color scale by using tones that produces from adding gray to specific color or adding complement of a color [31]. The shape information cleared by highlighting the 3D object using Phong rendering and edge lines draw in black color. Though, Northrup & Markosian is considered this shading algorithm complex and not easy to implement [32]. Additionally, Lum and Ma are presented an approach automating interactive volume rendering with NPR by using multi-texturing. The enhancements by using NPR include edge lines, hue varied shading and color depth cueing [33].

In the paper proposed by Sousa, Samavati, and Brunn an algorithm and technique for rendering triangular surfaces following an edge based stroke. This technique integrated drawing stroke direction and using light to depict shape features. Four stroke are selected to draw direction and use spotlighting. Feature lines are an important tool in 3D visualization to convey shape that significantly affected by the light [34]. A novel style of feature lines proposed by Xie et al. named as Photic Extremum Lines (PELs). Edge detection was selected for three dimension shape visualization and manipulated with the number, type and position of the light [35]. In 2008, a weight of illustrative rendering techniques combined to improve depth and shape of medical data. Many illumination and surface

details fused to control the weight for shading map [36]. Vergne et al. presented light warping approach to improve the view-dependent of 3D objects. The light ray warped each point of the surface for compressing the reflected light patterns [37].

Recently, hatching technique introduced in 3D scene taking into account three criteria which were the lighting, the object geometry, and its material to establish a coherent and consistent model texture mapping. The criteria offered tone, geometric motif orientation and geometric motif style respectively. In the loading step the triangle adjacency deduced easily from any 3D models by indexing the model vertices [38]. Lately, Xu, Gingold and Singh introduced an interactive modeling tool that discretely shaded 2D image to design a smooth 3D normal field. Smooth 3D normal fields could be gotten quickly for a variety of shapes by a toon shaded, or discrete tone image, or even de novo. First light directions estimated and calculated 3D normal along the object silhouette and at intersections from different light sources between isophotes. Then, the 3D normal propagated smoothly along isophotes, and subsequently the interior of the shape throughout. A perceptual experiment and comparisons to ground truth data were conducted to check the validity of the approach [39].

Materials and Methods

The following Figure 1 shows the steps of our proposed method and the detail explanation presented in the following subsections.

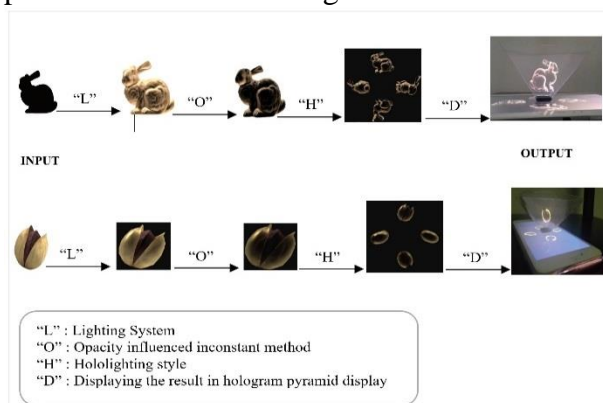


Figure 1: The steps of our proposed method

The hologram pyramid display

Our hologram pyramid display technology uses a mobile phone or tablet as a projector with two different sizes of pyramids. It is based on the Pepper's Ghost technique which uses special lighting with plate of glass or plastic rotated at a 45 degree angle. The pyramid was built with four sides of suitable reflective plastic, and the projector was placed on the top of the pyramid. The four plastic surfaces were shaped as a pyramid to support four views of the 3D objects. Mostly the hologram pyramid display presented very clear holograms in the dark environment. The datasets used in this research were standard data from Stanford University which was bunny and a pistachio object from [40].

Lighting Hologram Style

The lighting system used in this paper is adopted from our previous work. The point light was selected because it covers a certain space close to the light source by attenuating the light intensity [10]. The equation (1) below calculates the attenuation based on the distance to the light source:

$$att = 1.0 / (K_c + K_l * d + K_q * d^2) \quad (1)$$

where d represents the distance between the light source and the object and K_c , K_l and K_q represent a constant, a linear and a quadratic respectively. The constant factor K_c never becomes smaller than one because the intensity is augmented with certain distances. The linear and the quadratic factors multiply with distance to decline the intensity. The linear factor is less significant when the distance grows. On the contrary, the quadratic is less significant when the distance is small. Six point light sources were added to the object (above, upper left, upper right, bottom, lower left and lower right) to maximize the shape perception. The quadratic factor was removed from the attenuation equation due to the fact of the quadratic being insignificant at small distances compared to the linear factor as shown in equation (2). The attenuation equation

attenuated the intensity of each point light source.

$$att = 1.0 / (K_c + K_l * d) \quad (2)$$

Opacity Influenced Inconstant Method

Opacity influenced inconstant method is proposed by adding an additional variable (the opacity) to phong shading. The new shading method consisted of 4 fundamentals which were the ambient, diffuse, specular, and opacity. the RGB color of the 3D model is held by the ambient variable I_a and other 3 variables were diffuse I_d , specular I_s , and opacity I_o variables. Figure 2 shows the union of the 4 variables proposed to generate the hololighting shading method and the 3 variables of phong shading.

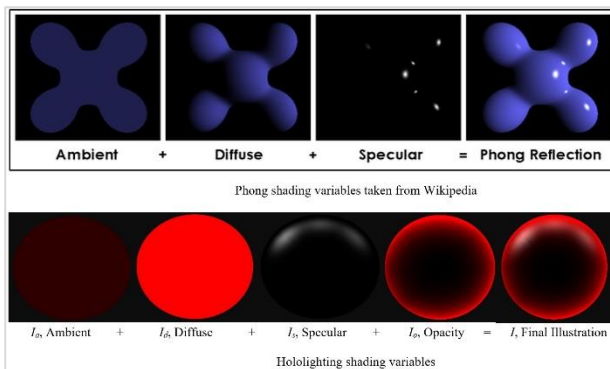


Figure 2: Phong and Hololighting shading variable

Diffuse Variable

The interaction between the light vector L and the surface (normal vector N) give the diffuse impact. Figure 3 clarified that impact on 3 points which are A, B and C. Point A has the highest intensity value when the angle θ between the surface and lighting vector is close to 0. When the angle θ is near 45 point B has less intensity.

A darker intensity got when the angle θ is almost 90 degrees at point C. Consequently for getting the diffuse variable, the dot product of surface vector and the lighting vector is conducted.

The diffuse variable I_d is given in equation 3; where h_d represents the diffuse reflection constant.

$$I_d = h_d (L \cdot N) \quad (3)$$

The multiplication of equation (2) and (3) produced final calculation of the diffuse variable as shown in equation (4) to attenuate the lights.

$$I_d = att * h_d (L \cdot N) \quad (4)$$

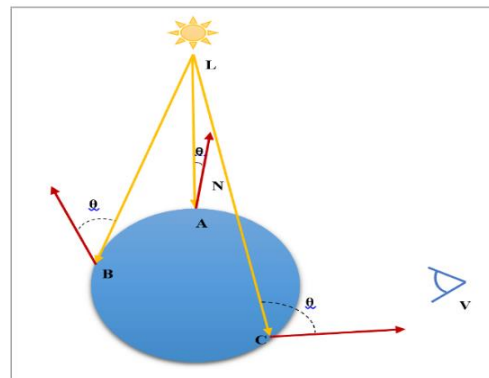


Figure 3: lighting vector, and normal vector, interaction

Specular Variable

The shining appearance that appears upper the object was given by the specular variable. The calculation of specular variable in phong shading used the dot product between the viewing vector V , and the light reflection vector, R . When the light reflection vector coincided with the viewing vector a highest intensity of specular can be achieved. However, the separations between the two vectors reduce the intensity. The glossiness factor controlled the degree of reduction. That means with a low glossiness, the shiny spot caused by the specular variable is larger than with a high glossiness value.

The lights position in specular variable has to be above, upper right and left object. Figure 4 showed the alignment between the reflection vector and the viewing vector is stated by α power. When the viewing not aligned with the reflection vector, the shining spot of the specular is small and α is large and vice versa. The following equation is the specular variable I_s , where the constant of the specular reflection is h_s .

$$I_s = h_s(R \cdot V)^\alpha \quad (5)$$

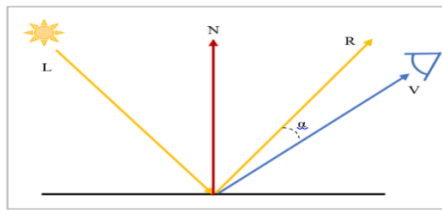


Figure 4: Viewing vector, and reflection vector, interaction

The impression of the specular variable was decreased from the 2 lights the upper right and above the object to adequate the shining on the object. In addition, the impact of the three lights under the object was omitted and the upper left light preserved the full influence on the object.

Opacity Variable

The fourth variable is opacity that added to phong shading to enhance the depth cues. The opacity can show the inside view of the 3D model. The viewing point must be parallel to the object to get highest impact of the opacity which means it remains at the eye position (0,0,0). Getting the opacity at the point I_o can be done by the dot product of the normal vector and the view vector as given in equation (6).

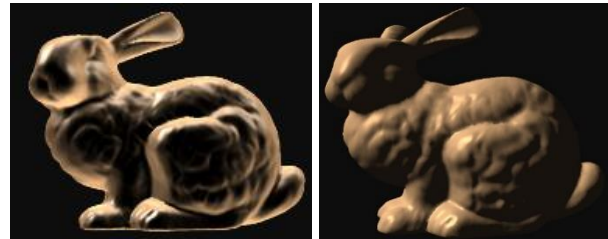
$$I_o = (V \cdot N) \quad (6)$$

The combination of the four elements that clarified above gave us the new shading method as shown in equation (7). Where, the assumption of the diffuse and ambient value is multiplied by opacity to show the inner view of the object, if it is available. Then, the shining appearance added to the object by adding specular variable.

$$I = \sum_{i=1}^{lights} ((I_a + I_d) * I_o) + I_s \quad (7)$$

A comparison was conducted between the original phong shading and opacity influenced inconstant method (the proposed shading method) as presented in Figure 5. In the proposed method, the bunny object seems to be

clearer and has improved depth and more dominant. An example of the proposed method on the 3D bunny model with 2 colors light gray and brown from different angles on black background shown in Figure 6.



(a) (b)
Figure 5: Comparison between (a) the new illustration shading and (b) Phong shading



Figure 6: Different angles and colors of the opacity influenced inconstant method

3D Hologram Rendering

3D hologram rendering can be got from dividing the screen to nine segments. The screen segmentation gave four view of the object from the right, left, front and back as illustrated in Figure 7. The glViewport was employed in OpenGL to perform the hologram rendering [11].

Obtaining the hologram views in our method examined two methods. The first method rotated the object by 90 degree around the camera, and the second one was done by rotation the camera 90 degree around the object. The first method was selected to rotate and got the four views of the 3D model because the impact of the opacity vanished from right and left views in the second method. The reason of this problem is the calculation of the opacity variable relay on the view vector. The impression of the two methods demonstrated in Figure 8.



Figure 7: The segmentation of holographic screen and object rotation.

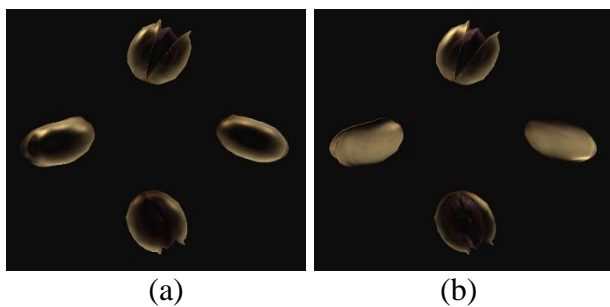


Figure 8: Pistachio model rendered by the Hololighting style: (a) object rotating (b) camera rotating

New Hololighting Style

The name of our new style comes from uniting 3D hologram rendering and the lighting hologram style. The opacity influenced inconstant method added to the hololighting style to produce a new hololighting style that enhances the depth cues and the shape of 3D objects.

Experiment, Results and Discussion

The experiment was achieved by using C++ and OpenGL and the survey was analyzed by using SPSS 21. On the Windows 10, processor Core (TM) i7, 2.50 GHz, RAM 16 GB , 64-bit.

The characteristics of the hologram have been identified based on the hologram illustration in several sites and studies. The validations of were designed to check whether the output (proposed hologram) have fully achieved the common characteristics of the hologram shading illustration. Table 1 summarized a comparison between the

hologram shading illustration characteristic, and hololighting style. Our proposed hologram had neatly accomplished the characteristics of hologram shading illustration, thus signifying the effectiveness of the developing the lighting hologram style; opacity influenced inconstant method, and 3D hologram rendering.

Table 1. Comparison between the hololighting style and hologram characteristic

	Hololighting Style	
Hologram Characteristic	Brighter color from the edges and continues to blacken towards the inner area of the object	√
	Omits the highlights from the bottom of the object and adds it to the top	√
	In the middle of the object, a transparent added to the object to show the inner stuff if its available	√
	Black background	√
	Shadow is not appear	√

Further comparison was carried out between our proposed hologram and computer-generated hologram from previous study [23] and Shutterstock website [41] as shown in Figure 9. The 3D objects that rendered using our proposed method have been observed to be clearer, more dominant and have better shape perception and depth cue.

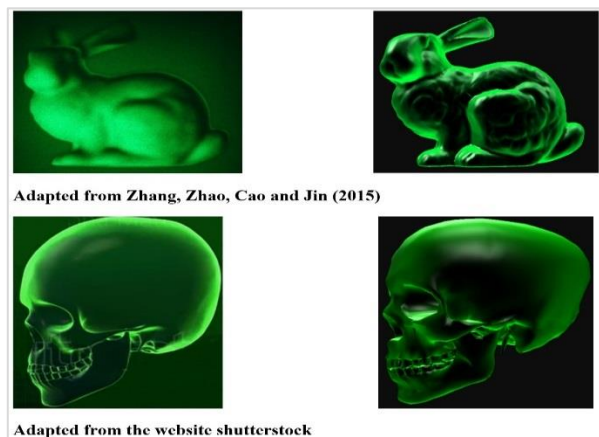


Figure 9: Comparing hololighting style with the hologram from previous studies

Researchers have used several different evaluation methods with a wide range of sophistication to validate NPR visualization. Some researchers [42-44] evaluated their output by doing statistical measurements on a questionnaire that obtain qualitative feedback. Other researcher [9, 33, 35, 37] matched their result to other result and styles that they desired to accomplish. Thus, the validation of the 3D rendering was not easy because as the old saying by Herbert George Wells goes “beauty is in the eye of the beholder”. In spite of that, in this paper, the experimentations phase was taken into account the user’s acceptance of the new proposed style.

The validation of the depth cues was carried out by using a survey. Where, the respondents were the graduate and undergraduate students of computer graphics department at the Faculty of Computer Science and Information Technology, UPM (University Putra Malaysia). The numbers of respondents were 124 students (95 undergraduate students and 29 graduate students). The gender of the respondents was 55 male and 69 female in age 22-24 of undergraduate students and 26-35 of graduate students.

A brief introduction was presented to the students to give them an idea about our study and explain the purpose of our survey. In addition to that, the presentation gave a description to the meaning of the shape, depth cue, standard shading method, and our proposed method.

First, the respondents were requested to evaluate the volume (depth) of the object that rendered by the opacity influenced inconstant method by asking them to answer the following question with Yes or No “Did the virtual objects appear to have real depth/volume?”. The positive rate of the respondents was 94.35% against 6.45 % where 117 students answer “Yes” the object have very good depth. However, eight students gave “No” as an answer.

Next, two images were presented to the respondents as shown in Figure 10. Then, the respondents were requested to gauge the depth

cue in both images. Where, the first image presented the objects appearing on the 2D display and the second one displayed the object in the hologram pyramid display. The choices in the questionnaire were between 1 and 5, where 1 represented not well and 5 represented very well.

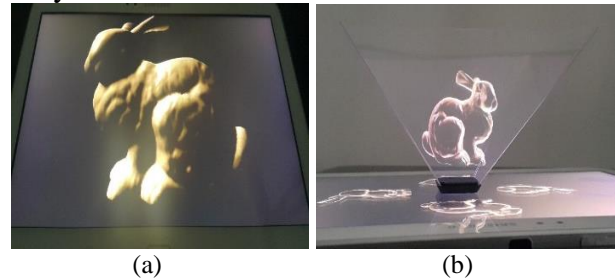


Figure 10: A comparison of the depth cue for an object on (a) 2D display (b) 3D hologram display

Figure 11 demonstrated the responses provided by the students. Our result revealed that 57 students noted that 3D hologram pyramid display is very well while only 6 students who do not constitute with them where the latter observed that 2D display is very well.

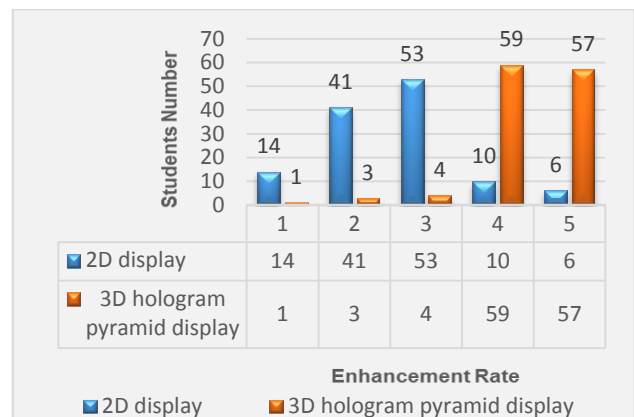


Figure 11: Depth cues enhancement rate of an object displayed on 2D display and 3D hologram pyramid display

Similarly, there is only one student observed 3D hologram pyramid display is not well whereas 14 students noted the opposite. The enhancement rate of the depth cue was 4 and 5 in the hologram pyramid display. Generally, the respondents fall in with the 3D hologram pyramid display could provide improved depth cues of the object compared to the traditional two dimensional displays.

The last question to validate the depth cues was which offered better depth cues on the hologram pyramid display, the traditional phong shading or the opacity influenced inconstant method. Figure 12 clarifies the influence of both methods on the bunny object in the hologram pyramid display. The respondents noticed the back of the bunny in the traditional shading was barely seen. The selected method by the respondents was the opacity influenced inconstant method at the rate of 90.3% as to the traditional method rate which was 9.7 %. The quality of the images produces by our proposed method was preferred when compared to the traditional method.

Conclusions

As shown in this work, the opacity influenced inconstant method achieves our objective for enhancing the depth cues. In addition, it can show the inner stuff of the objects if it is available. Our study concluded that the hologram accomplishes the characteristics of hologram shading illustration, thus demonstrating the efficiency of developing the lighting hologram style; opacity influenced inconstant method, and 3D hologram rendering. According to the survey conducted, most the respondents prefer rendered objects in the opacity influenced inconstant method when compared to the traditional method.

There are still many works that lie ahead to be undertaken in the future, like testing more lighting system to enhance the object and present the hologram. Also, the shading phase can be improved and applied to other types of objects that can represent the opacity impact. Finally, designing a bigger pyramid for a bigger screen can improve the presentation of the 3D model.

Conflict of interest

The authors declare that there is no conflict of interest.

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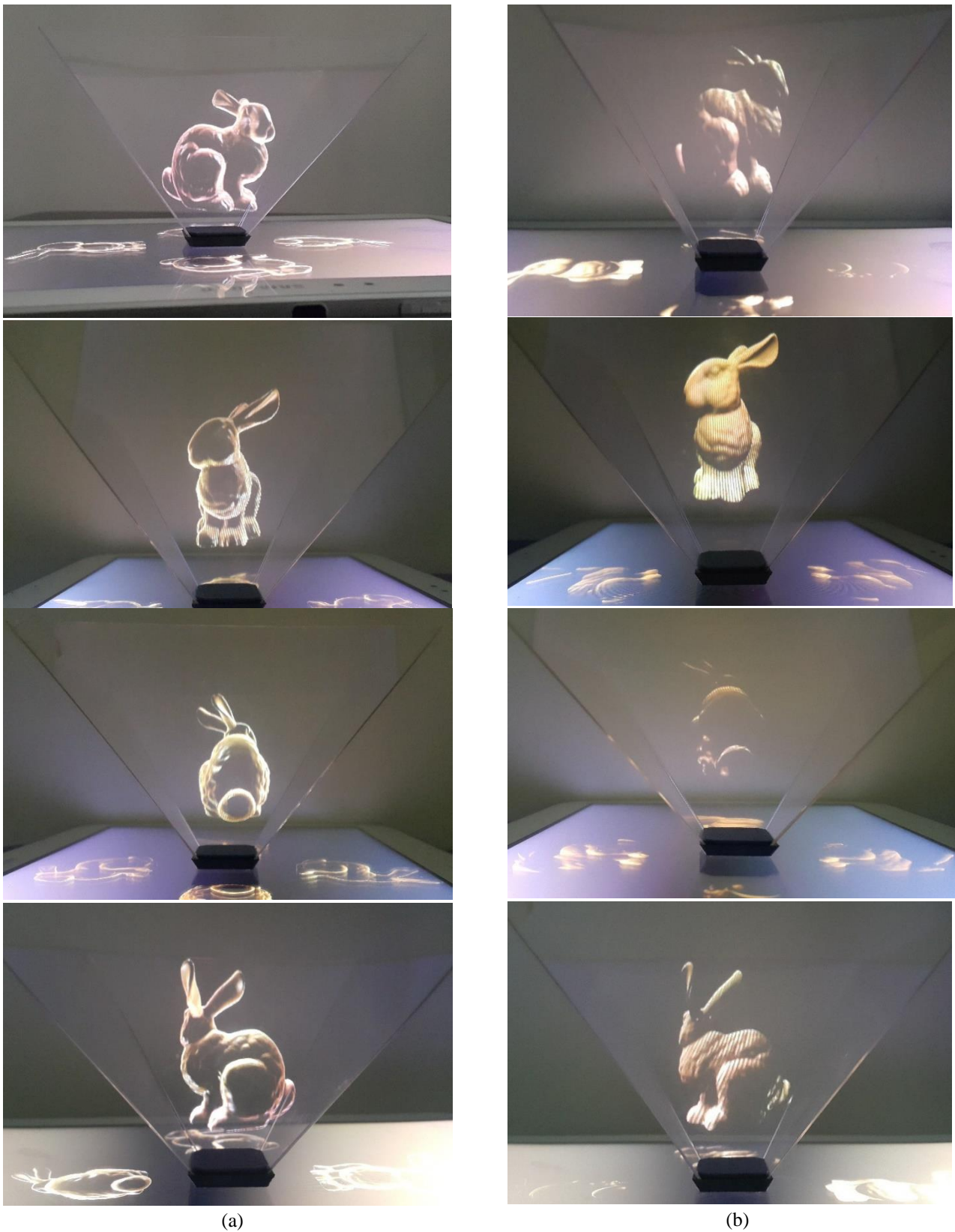


Figure 12: hologram pyramid display present bunny object by (a) the opacity influenced inconstat method, (b) traditional shading method.