International Science and Technology Journal
المجلة الدولية للعلوم والتقنية

Volume 34 العدد
Part 1 المجلد
April 2024 ابريل

تم استلام الورقة بتاريخ:25/ 2 /2024م وتم نشرها على الموقع بتاريخ:27/3/2024م

Near to Real-time Computer Generation of 3D Holoscopic Images

www.doi.org/10.62341/namo2725

Mahmoud Geat Eljadid[1], Amar Aggoun[2], Osama H. Attallah[3]

1. Associate Professor. Dept. of Software Engineering, Faculty of Information Technology, Tripoli University, Libya. P.O. Box: 13086
2. Professor. School of Mathematics and Computer Science, University of Wolverhampton. Wolverhampton, UK.
3. Senior Lecturer. Alexandria University, Research Medical Institute, Department of Biomedical Engineering, Alexandria, Egypt.

*[1] Corresponding: E-mail: meljdid@hotmail.com, M.Eljadid@uot.edu.ly

Abstract.

Generating a truly photo-realistic 3D real-time view capability in an ergonomic and cost effective manner is a crucial engineering challenge. In this paper, the advanced integral imaging methodology is proposed that is based on microlens arrays to generate 3D Holoscopic images by the intersection ray bundle that defines each image point in the associated scene at the correct spatial place. The core idea of the novel algorithm reported in this paper is to accelerate the computer generation of photo-realistic still 3D Holoscopic images based on multiprocessor ray-traced system. Consequently a significantly reduce in running time is successfully completed. Multiple subjective and objective images quality assessments are addressed and as a result there was not any observable distortion in images quality. The results obtained are very satisfactory and for the first time that the new hybrid algorithm has achieved the saving in terms of execution rendering time approximately (60 % - 78 %) that a near to real-time computer generation of 3D Holoscopic images.

Keywords: Real-time Computer Generation content of 3D Holoscopic Images, Interpolation 3D integral images, Computer Graphics, Spatial Coherence, Ray Tracing, 3DTV.

تم استلام الورقة بتاريخ:25/ 2 /2024م وتم نشرها على الموقع بتاريخ:27/3/2024م

الاقتراب من الزمن الحقيقي لتكوين الصور المتكاملة ثلاثية الابعاد

www.doi.org/10.62341/namo2725

د. محمود غيث محمود الجديد[1]، أ. د. عمار اقون[2]، د. أسامة حسن يوسف[3]

[1]قسم هندسة البرمجيات، كلية تقنية المعلومات، جامعة طرابلس.

[2]كلية الرياضيات وعلوم الحاسب جامعة ولفرامثون، بريطانيا.

[3]قسم الهندسة الحيوية، جامعة الاسكندرية، جمهورية مصر العربية.

الملخص:

تكوين الصور الحقيقية المتكاملة ثلاثية الابعاد للوصول الي الزمن الحقيقي في التكوين يعتبر من أهم الاهداف الهندسية. الورقة البحثية تستخدم النظام الحديث لتقنية الصور المتكاملة ثلاثية الابعاد المعتمدة على عدسات صغيرة متراصة بجانب بعضها البعض على هيئة مصفوفة، وهنا نستخدم 64 عدسة في الإطار الوحد. وذألك بهدف الاقتراب من الزمن الحقيقي لإنتاج الصور المتكاملة قمنا بتطوير خوارزمية جديد تسمي الاقتراب من تكوين الصورة المتكاملة ثلاثية الابعاد مستخدما اعادة الاسقاط المنظوري والاستكمال الخطي معا وذلك بإيجاد المعلومات المفقودة التي تظهر اثناء تحريك الة التصوير الافتراضية موضع الي آخر. لضمان ان تكون الصور المتكونة قابلة للاستعمال وغير مشوهة قمنا باستخدام طريقة نسبة قدرة الاشارة الي قدرة التشويش. النتائج المتحصلة عليها تظهر حجم التسريع الحاصل في تكوين الصور الثلاثية الابعاد باستخدام هذه التقنيات الجديدة. الطريقة الجديدة تعتمد بالأساس على المعالجات المتعددة وخوارزمية تتبع الشعاع وأظهرت نتائج هامة.

الكلمات المفتاحية: خوارزمية تتبع الشعاع للمعالجات المتعددة، الزمن الحقيقي لتكوين الصور المتكاملة ثلاثية الابعاد، الرسومات الحاسوبية، الاستكمال الخطي للنقاط المفقودة، وسائل العرض ثلاثية الابعاد

تم استلام الورقة بتاريخ:25/ 2 /2024م وتم نشرها على الموقع بتاريخ:27/3/2024م

1. Introduction

The new developed algorithm proposed in this paper is taken advantages of the lens view algorithm re-projection between cylindrical lenses micro-images and interpolation algorithms are combined in one complete developed software in order to speeding up the production of a single 3D Holoscopic image frame are adapted here. Temporal coherence between sequences of frames is used and the missed information is produced by allocating two point arrays. The first point array is to store the pointimage of the prior to frame and the second point array is to register the pointimage of the follow frame. Calculate the average of pointimage color elements *(R, G, B)* of the odd pointimage arrays, to produce an associated new pointimage colors of the even frames are registered on the new projection plane. This process is illustrated in Figure 1. The advantage of a new algorithm introduced is to adopt an integral ray tracing based on Parallel Ray-Traced System "Adopted Tachyon" as renderer [1-11], lens view algorithm to take an advantage of information exist and reuse it to generate a new micro-image and interpolation technique to overcome the missed information between microimages[12].The new technique is used a multiprocessors ray tracing system as render although the ray tracing is an exhausted time in terms of rendering execution time but the image generated is realistic. Therefore the viewed 3D still image displays reality because of the ‘solidity’ of the objects in the scene. The 3D integral images is also refers to 3D Holoscopic images used Microlens Array type. The 3D Holoscopic imaging lens view algorithm re-projection between cylindrical lenses and interpolation algorithm are adapted in order to increase the rendering time of generation of 3D Holoscopic image frames as well.This allows reuse of results obtained for one micro-image to computer generate the neighboring micro-image and hence avoiding ray tracing all the pixels and interpolated the missed pixels taking the advantage of the spatial coherence between micro images.The *Peak-Signal-to-Noise-Ratio* quality measurements are used to

International Science and Technology Journal
المجلة الدولية للعلوم والتقنية
Volume 34 العدد
Part 1 المجلد
April 2024 ابريل
المجلة الدولية للعلوم والتقنية International Science and Technology Journal ISTJ
تم استلام الورقة بتاريخ:25/ 2 /2024م وتم نشرها على الموقع بتاريخ:27/3/2024م

ensure that there is not any visible distortion of the new generated image.

```
While not end of camera file
  {
    Check if first frame
        Generate theinitial frame of the sequences using fully ray  tracing
        algorithm.
     Check if even frame
Reproject the pixels from the previous frame onto new frame.
```

Figure 1. Pseudo-code of enhanced 3D integral imaging ray

2. Integral Imaging Ray Tracing

This paper gives an introduction to ray tracing, including a brief explanation of the global illumination problem, and the various accelerating techniques are used to reduce the computational cost in ray tracing. Ray-traced is a light simulation and is one of the estimated solutions to the global illumination matter. The proposed global lighting problems are a lights transport problems. Photon is emitted by light sources is transports that means of reflection and refraction photons in 3D dimension world. The foundational transports equations used to explain the global illuminating matter is called the rendering equation. Because of the human eye is sensitive to radiance values. They are calculated over a very specific area and a solid angle. All equations that described the transport of radiance are repeated again integral equation with a fixed integrations domains.Ray tracing is simulated light rays, that reflecting from objects seen by the microlens in an opposite manner. It is traced initial rays from the observer’s eye to the objects in the scene. This simply procedure determines the color and the intensity of a point at the closest intersection of a initial ray with an object. Ray tracing is performed visible surface determination completely separate for each pixel in the rendered image. First image is projected textures and second is procedural texturing. The earlier is used wherever it is more suitable to simulate the surface appearance

تم استلام الورقة بتاريخ:25/ 2 /2024م وتم نشرها على الموقع بتاريخ:27/3/2024م

of an object by coloring it according to an image rather than by use mathematical calculations. All the explained quality of ray traced migrates to 3DHoloscopic image and can make a massive impact to practical concern in computer graphics software to facilitate 3D Holoscopic image monitors. This will increase the observation of the photo-realism for the viewer. The computer generation of 3D Holoscopic image using ray tracing system was reviewed with an explanation of its optical camera system model [12]. The technique of computer generation 3D Holoscopic image is replayed use a LCD by overlay it with a cylindrical sheet. This technique also allows all computer graphics concepts and tools to gain from the 3D with the use of a low-cost cylindrical sheet [13-19].

3. 3D Holoscopic Image Interpolation Algorithm

The core idea of the proposed algorithm introduces a unique approach by ray traced renderer and interpolating technique to allow avoiding ray traced of the missed pixels to generate newly fresher missed information associated with their color by creating two point arrays. In this method the microimages are divided into odd ones and even ones microimages. The odd-one microimages defines the microimages occupation the odd position in still image i.e. first, third, fifth, seventh and so on till the rest of the micro-images. Whereas the even microimages defines the microimages occupation the even positions in the still image i.e. second, fourth,..., eighth till the rest of the micro-images. The odd microimages are created by use the 3D Holoscopic image lens view technique, containing full ray traced the missed 3dpixels. The even microimages are created as well by use the 3D Holoscopic image lens view technique, excluding the missed pixels are generated through interpolating of the information from neighboring odd microimages. To create one even microimage, two point arrays are allocated to hold the point image from the neighboring odd microimages. The color elements (*R*, *G*, *B*) of the missed pixels in even microimages are gained by simply calculate and find out the average of point image color elements (*R*, *G*, *B*) of the point image arrays corresponding the neighboring odd microimages. The related to the produced new point image colors are registered on the point image array as shown in Figure 2 , Figure3, Figure 4 and Figure 5.

```
col.r = ((np1.r + np2.r)/2);
col.g = ((np1.g + np2.g)/2);
col.b = ((np1.b + np2.b)/2);
image[address    ] = col.r;
image[address + 1] = col.g;
image[address + 2] = col.b;
flt runtime; timerstart(); /*start ray tracing timer
```

Figure 2. Piece of code of interpolation 3D integral imaging ray tracer.

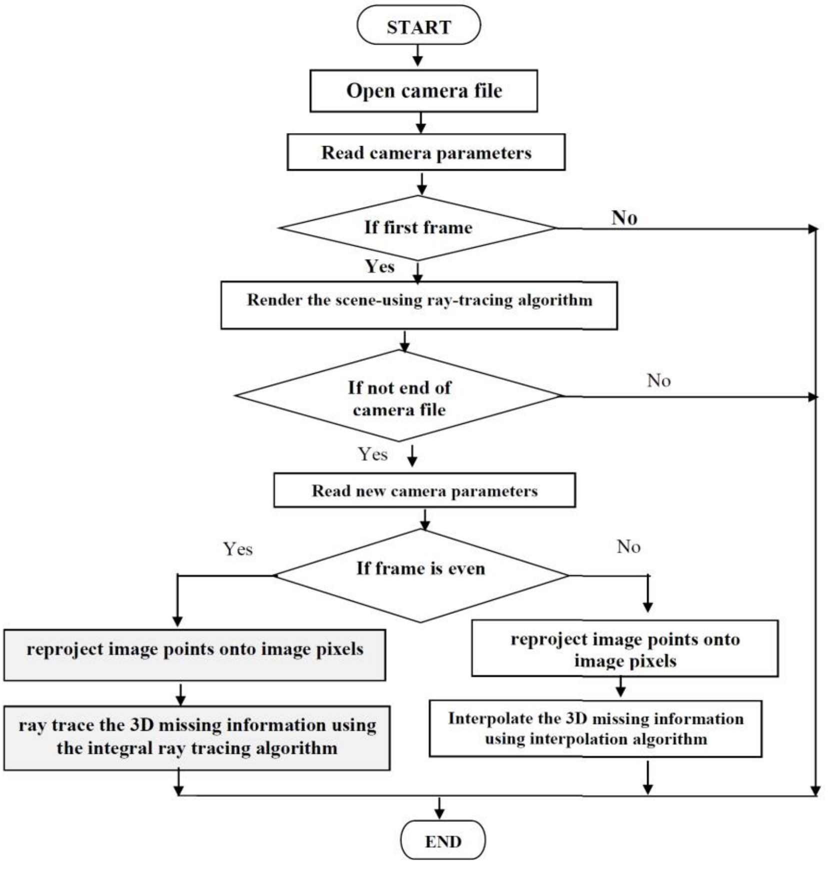


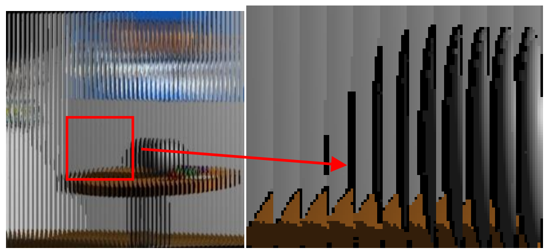
Figure 3. Flowchart of proposed interpolation algorithm and lens view algorithm

International Science and Technology Journal
المجلة الدولية للعلوم والتقنية

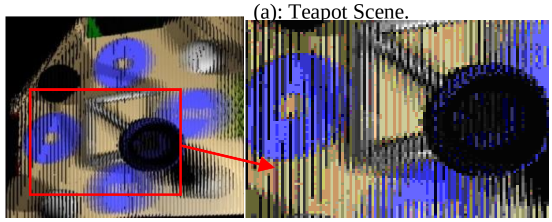
Volume 34 العدد
Part 1 المجلد
April 2024 ابريل

تم استلام الورقة بتاريخ:25/ 2 /2024م وتم نشرها على الموقع بتاريخ:27/3/2024م

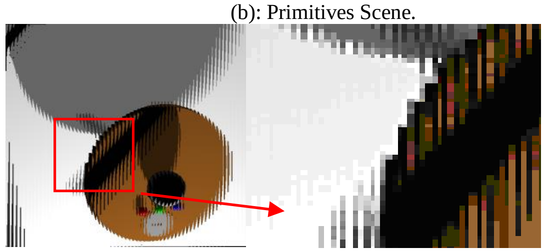
.



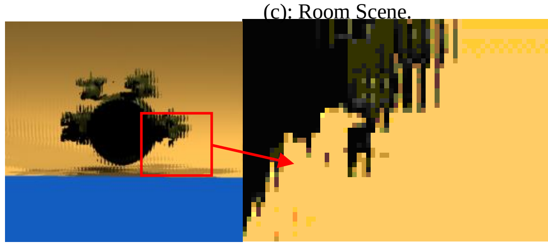
(a): Teapot Scene.



(b): Primitives Scene.



(c): Room Scene.



(d): Small-balls Scene.

Figure 4. (a-d). Regions are not filled in prior to still image, is colored black (a) Room scene (b) Primitive scene (c) room scene different view (d) small-balls scene.

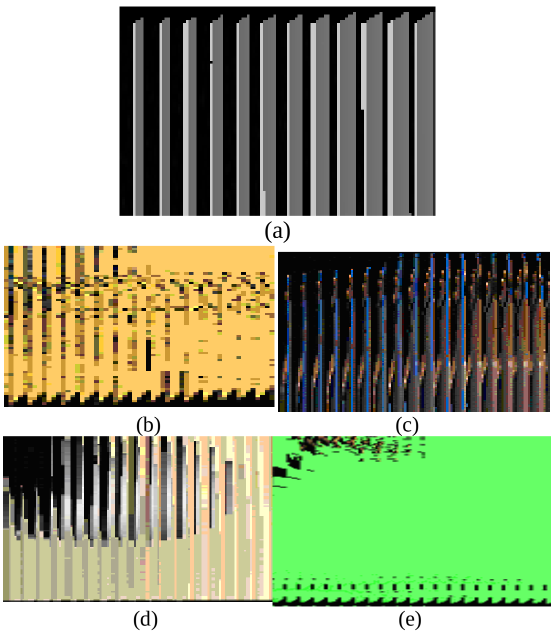


Figure 5. (a-e). Enlarged views of particular areas of (a) room scene (b) small-balls scene (c) teapot scene (d) primitive scene (e) tree scene.

An practical results of the missed information is illustrated in Fig. 6. After interpolating the missing pixels, the newly fresh by created points are saved in the point image. The associated colours are registered on the pixel image and their flags are equal to ‘0’. As shown in Figure 6, Figure 7.

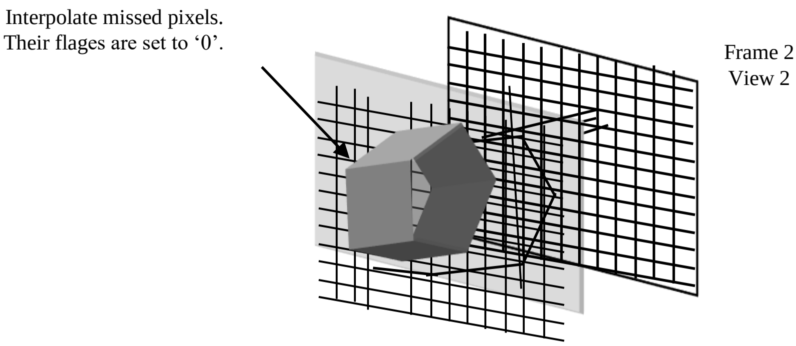
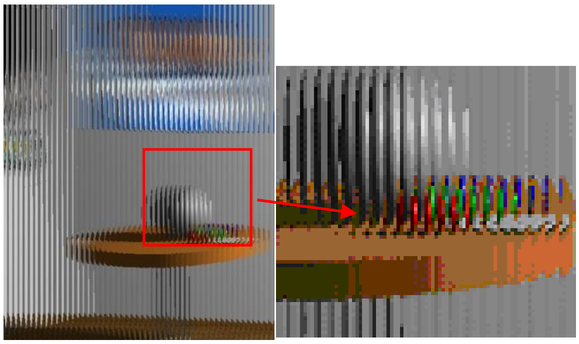


Figure 6. Interpolated missed pixels.

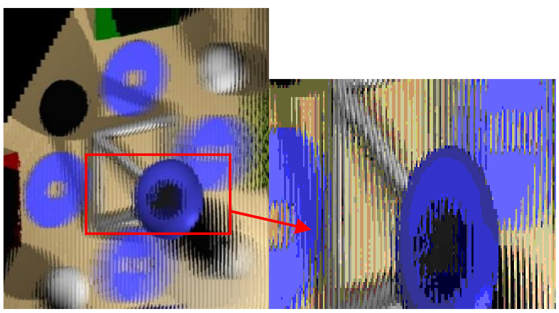
International Science and Technology Journal
المجلة الدولية للعلوم والتقنية

Volume 34 العدد
Part 1 المجلد
April 2024 ابريل

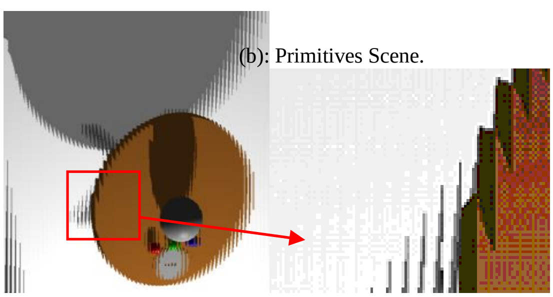
تم استلام الورقة بتاريخ:25/ 2 /2024م وتم نشرها على الموقع بتاريخ:27/3/2024م



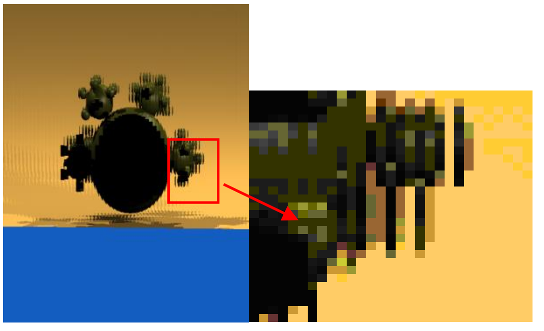
(a): Room Scene.



(b): Primitives Scene.



(c): Room Scene.



(d):Small-balls Scene.

Figure 7. (a-d). Practical results overcoming the missed pixels seen fig. 5: (a) room scene (b) primitive scene (c) room scene with different view, and (d) small-balls scene.

Completely, similar procedure is then repeated again, by use the image points of the prior and next still images to create the newly refresh still image The odd 3D integral imaging frames are produced by re-projecting the image points on pixel image and the missing pixels are obtained by using interpolation. The even 3D integral imaging frames are produced by re-projecting the image points on the pixel image and the missing pixels are generated by using the integral ray traced algorithm again.

4. Experiments and results

Measure the Quality of 3D Holoscopic image to assess the quantity of image distortion among cylindrical lenses are developed. This formula is used to compare the equality in terms of distortion of two images is to calculate the peak signal to noise ratio ($PSNR$) as illustrated in Figure 8. The first 3D still image $f(i, j)$ is produced by using the full integral ray traced renderer, and the subsequent 3D still image $g(i, j)$ is gained by using 3D Holoscopic image lens view and 3dinterpolation formula that are already explained. The results obtained are illustrated in Table 1. Figur 9, Figure 10, Figure11. are shown enhancing 3D integral images that are gained using hybrid algorithm combining 3D integral images lens view and interpolation .

تم استلام الورقة بتاريخ:25/ 2 /2024م وتم نشرها على الموقع بتاريخ:27/3/2024م

$PSNR_{AVR} = 35.5185\ dBs$

The practical results illustrated in Table 2 shows the significantly decreasing in terms of rendering running time that have been accomplished as comparing the use the full integral ray traced method when integral imaging lens view and integral interpolation algorithms are used.

```
% mx,nx are the size of the image (frame)
% ori is the original frame or image
% cons is the reconstructed frame or image
% RMSE is the root to mean square error
% PSNR is the peak signal to noise ratio
[mx,nx]=size(ori);
RMSE=sqrt((1/(mx*nx))*(sum(sum((double(cons)
double(ori)).^2))));
PSNR=20*log10(255/RMSE);
```

Figure 8. Piece of code of to measure the image quality MatLap s/w.

Table 1: Measurement of Quality of 3D integral images animation of teapot scene.

Scenes Teapot	RMSE Red	RMSE Green	RMSE Blue	RMSE Average	PSNR(dB)
Frame 99	22.8447	18.9667	19.5755	20.4630	35.0211
Frame 100	27.2763	22.2156	21.9914	23.82776	34.3600
Frame 101	23.3528	19.4864	19.8478	20.8956	34.9303
Frame 102	27.6892	22.8421	22.5198	24.35036	34.2657
Frame 103	24.1023	20.0936	20.1222	21.43936	34.8187
Frame 104	28.2723	23.3329	22.6439	24.7497	34.1951
Frame 105	24.3423	20.4135	20.2650	21.6736	34.7715
Frame 106	28.7464	24.0092	23.2379	25.3311	34.0943
Frame 107	24.7025	20.8879	20.6101	22.0668	34.6934
Frame 108	29.1157	24.5675	23.6282	25.7705	34.0196
Frame 109	25.4550	21.8205	21.4098	22.8951	34.5334

تم استلام الورقة بتاريخ:25/ 2 /2024م وتم نشرها على الموقع بتاريخ:27/3/2024م

Table 2: Rendering computations times of the frames using different algorithms.

Scene	Number of frames	Total rendering time of frames using full integral ray traced (in sec)	Total rendering time of frames using integral lens view algorithms (in sec)	Total for rendering time of frames using 3D integral interpolation algorithms (in sec)	Total saved times using integral lens view algorithms (in sec) & (%)	Total saved times using 3D integral interpolation algorithms (in sec) & (%)
Teapot	612	1836	1040	520	796 sec (43 %)	1316 sec (72 %)
Room	634	1268	697	496	571 sec (45 %)	772 sec (61 %)
Small-balls	421	842	379	189	463 sec (55 %)	653 sec (78 %)
Primitives	512	1024	665	333	359 sec (35 %)	691 sec (68 %)
Tree	612	9017	5202	3672	3815sec (42 %)	5345 sec (59 %)
Gears	612	3060	2570	1224	490 sec (16 %)	1836 sec (60 %)

From Table 2, clearly noticed that a significantly decreasing in computations time is gained by use the new integral lens view algorithm. A (*16% - 55%*) reduction in rendering time for different tested scenes is succeeded by using the lens view procedure when compares to full ray traced, depending on the complexity of the scene. This makes the production of a sequence of 3D Holoscoic imaging frames three times faster than its original running speed before implementing the integral lens view algorithm. The proposed hybrid algorithm saving up to 3815 seconds (*42 %*) of computation time of Tree scene. It can clearly be noticed that more significantly decreasing in running time is accomplished by the use of 3D integral interpolation algorithm. Savings up to (*59 % - 78 %*) as compares to the ray traced time of different scenes is achieved by the use the interpolation process. The method adopted saving up to 5345 second (*59 %*) of the Tree scene rendering time.

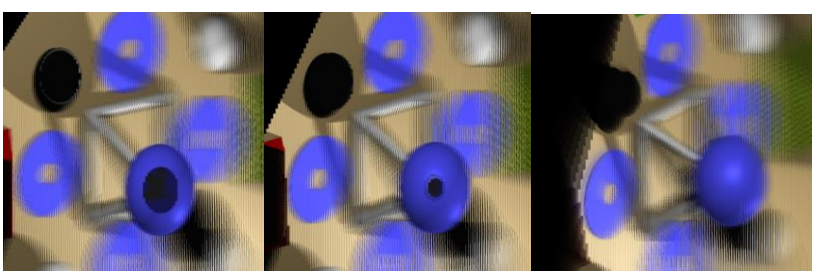
تم استلام الورقة بتاريخ:25/ 2 /2024م   وتم نشرها على الموقع بتاريخ:27/3/2024م

(a): Teapot scene frame 0. (b): Teapot scene frame 99. (c): Teapot scene frame 188.

(d): Teapot scene frame 345. (e): Teapot scene frame 402. (f): Teapot scene frame 553.

(g): Teapot scene frame 600. (h): Teapot scene frame 620. (i): Teapot scene frame 650.

Figure 9. (a-i): Interpolated& Lens view frames of teapot scene.

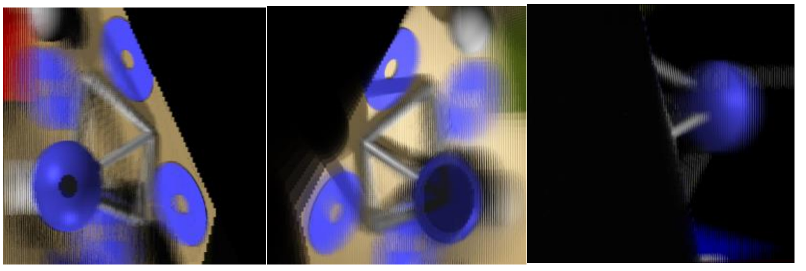


(a): Primitives scene frame 1. (b): Primitives scene frame 49. (c): Primitives scene frame 99.

International Science and Technology Journal
المجلة الدولية للعلوم والتقنية

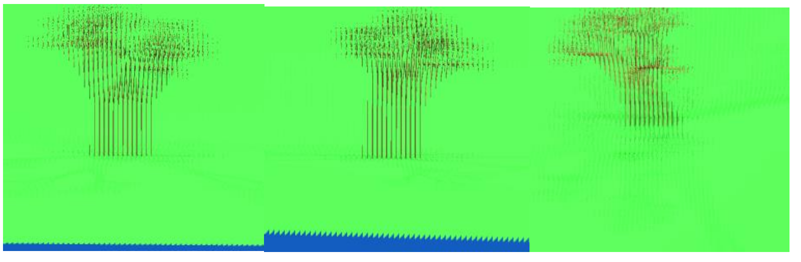
Volume 34 العدد
Part 1 المجلد
April 2024 ابريل

تم استلام الورقة بتاريخ:25/ 2 /2024م وتم نشرها على الموقع بتاريخ:27/3/2024م

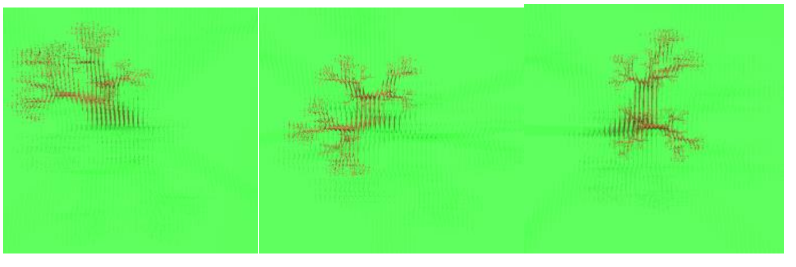


(d): Primitives scene frame 189. (e): Primitives scene frame 245. (f): Primitives scene frame 399.

Figure 10 (a-f). Interpolated & lens view frames of primitives scene.



(a): Tree scene frame 1. (b): Tree scene frame 99. (c): Tree scene frame 199.



(d): Tree scene frame 299. (e): Tree scene frame 394. (f): Tree scene frame 594.

Figure 11(a-f): Interpolated & lens view frames of tree scene.

5. Conclusion

Generate truly 3D Holoscopic image in real-time platform is an engineering challenging. This paper addressed algorithm that near to reach the target. The 3D Holoscopic image lens view between

تم استلام الورقة بتاريخ:25/ 2 /2024م وتم نشرها على الموقع بتاريخ:27/3/2024م

cylindrical lenses algorithm and interpolation algorithm are adapted to more accelerate the generation of 3D Holoscopic image frames. Consequently a significantly decreasing in running time is achieved. The two subjective and objective images quality calculation are described and it is found out that the significantly reduction in rendering time is achieved without any visible distortion degradation in still image.

6. References

[1]Mahmoud G. Eljadid, A. Aggoun, O. H. Youssef, " Computer generated content for 3D TV", in Proc conf. Kos Island, Greece, May 2007.

[2]Mahmoud G. Eljadid, "3D Content ComputerGeneration for Volumetric Displays," PhDThesis, Brunel University West London, 2007.

[3]Mahmoud G. Eljadid, A. Aggoun, " Medical 3D Integral Images Visualization in True Space" *Lecture Notes on Software Engineering, Vol. 4, No. 2, May 2016,* DOI: 10.7763/LNSE.2016.V4.229.

[4]M. G. Eljdid, A. Aggoun, O. H. Youssef," Enhanced Still 3D Integral Images Rendering Based on Multiprocessor Ray Tracing System" Journal of Image and Graphics, Volume 2, No.2, December 2014 doi: 10.12720/joig.2.2.117-122.

[5]M. G. Eljdid, A. Aggoun, O. H. Youssef,"Enhanced Techniques 3D Integral Images Video Computer Generated" Proceedings of the International conference on Computing Technology and Information Management, Dubai, UAE, 2014. ISBN: 978-0-9891305-5-4 ©2014 SDIWC.

[6]A. Aggoun: "3D holoscopic imaging technology for real-time volume processing and display," High Quality Visual Experience Signals and Communication Technology, 2010, pp. 411-428.

[7]http://www.3dvivant.eu/ contract no: IST-7-248420-STREP, Program FP7-ICT-2009-4. 1st Newsletter June 2010. Intermediate Dissemination Report 20th April 2012.

تم استلام الورقة بتاريخ:25/ 2 /2024م وتم نشرها على الموقع بتاريخ:27/3/2024م

[8]Parallel/Multiprocessor Ray Tracing Software. [Online]. Available jedi.-ks.-uiuc.-edu/-~johns/-raytracer/

[9]A. Aggoun, E. Tsekleves, D. Zarpalas, P. Daras, A. Dimou, L. Soares, and P. Nunes, "Immersive 3D holoscopic system," IEEE Multimedia Magazine, Special Issue on 3D Imaging Techniques and Multimedia Applications, vol. 20, issue 1, pp. 28-37, Jan.-Mar. 2013.

[10] O. H. Youssef and A. Aggoun, "Coherent grouping of pixels for faster shadow cache," in Proc. 3rd Holoscopic Computer Graphics, 3DTV Conference, Tampere, Finland, 8-9 June 2010.

[11] Osama H. Youssef, "Acceleration Techniques for Photo-Realistic Computer Generated Integral Images," De Montfort University, PhD Thesis, 2004.

[12] Mahmoud G. Eljadid, A. Aggoun, O. H. Youssef," **Lens View RenderingFor Efficient Computer Generation Of3D Integral Images"** Al-JAMEAI Journal, Volume 2, Issue 38, Autumn 2023, ISSN: 2706 -5820.

[13] S. Min *etal*, "Three-Dimensional Display System Based On Computer-Generated Integral Imaging," *Stereoscopic Display and Virtual Reality Systems VIII proc. Of the SPIE*, Vol. 4297, pp. 187-195, 2001.

[14] Halle, M. W. *et al*, "Fast Computer Graphics Rendering for Full Parallax Spatial Displays," *Practical Holography XI and Holographic Materials III Proc. Of the SPIE*, Vol.3011, 1997.

[15] Naemura T., T. Yoshida and H. Harashima, "3D Computer Graphics Based on Integral Photography," Optics express, Vol. 8(2), pp. 255-262, 2001.

[16] Grahm E. Milnthorp, "Computer Generation of Integral Images using Interpolative Shading Techniques" De Montfort University, PhD Thesis 2003.

[17] Athineos, S. Sgouros, N." Photorealistic integral photography using a ray-traced model of capturing optics" Journal of Electronic imaging Oct-Dec 2006/vol. 15(4).

تم استلام الورقة بتاريخ:25/ 2 /2024م وتم نشرها على الموقع بتاريخ:27/3/2024م

[18] Motoki, T., Isono H. and Yuyama I., *"Present status of three-dimensional television research", Proc.IEEE'83*, pp. 1009-1021, 1995.

[19] Zafar M. , Jiangbin z. , Idress A., Muhammed I., Amir S. "High-Performace GPU Planetary-Scale Terrain Visualization" Proceedings of 5th ICIGP 2022 Conference.