A Study on the Effect of Environmetal Conditions on the Data Quality of Scanned Images Collected from the 3D Human Body Light Scanners

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Abstract

This article presents the results of the study on the influence of environmental conditions on the quality of human body scan images collected from 3D scanners using structured light with impact factors including: the scanning distance, backdrop color and environmental light intensity. In this paper, we used Meshlab software for image grading. We also used grayscale valueof Histogram diagram and thenumber of 3D scanned pixels which are determined to evaluate the data quality collected from the 3D human body light scanners. In addition, the study used Design Expert 6.0 software for analyzing collected data and checked the effect of those factors. The experimental results are given to clarify the effect of considered factors.

Keywords: Environmetal conditions, structure light, 3D scanners, the quality of 3D graphics.

1. Introduction

Nowadays in the world there are many types of 3D scanners using light of different structures. 3D body scanning equipment has also been developed by many companies such as: [TC]^2 Cyberware, Human Solutions, TELMAT, Hamamatsu, Wicks and Wilson, BodyskannerTM...etc. Although these machines have been accepted in the industry, they still have disadvantage of high cost that has limited the demand. Besides, shooting conditions and setting data processing system are complicated. Therefore, the design and manufacture of a low-cost device that still ensures the required measurement is essential in current conditions. In published research [1], we have studied the method of 3D measuring application with light code structure gray to measure the human body and establish some calculation scanning the human body with the length x Wide = 2.2 m x 1 m.This instrument provides the surface data of the sample, which can then determine the shape and size of the human body. However, to obtain accurate and proper scan data, the factors such as the equipment, the measuring environment, the position of the object during measurement have a great influence. In this paper, we present the results of the study on the influence of environmental conditions on the quality of human body scan images collected from 3D scanners using structured light with impact factors including: the scanning distance, backdrop color and environmental light intensity As a result, we determine the optimum conditions for 3D scanning with scanners we have built.

In the world and in Vietnam there have been some studies on this issue. For each type of scanner, scanning field and scan object, it is necessary to determine the optimum scanning distances to ensure the best quality of the scanned images. In 2012, The author Jing Tong along with his colleagues [2] designed the Microsoft Kinect scanner with an optimal scanning distance of 100cm. By 2015, the KScan3D 3D scanning engine using the built-in light beam with the optimal scanning Distance was introduced and defined as invalid source specified.

Research on the effects of light intensity of ambient enviroment: The intensity of illumination is the specific characteristic of the surface being illuminated on the surface of the light intensity sensed. Unit of measure is Lux (lx). This is also an important influencing factor on the quality of scanning image. In 2007, influential study by Sophie Voisin, Sebti Foufou, Frédéric Truchetet, David Page, and Mongi Abidi [3] Concluded that: Ambient light has a strong influence on the accuracy of the wavelength range from the light of the structure. In 2013, Mohit Gupta, Qi Yin, Shree K. Nayar studied static outdoor scanning using three Scan-only and Concentrate-and-Scan scans, Spread-and-Avergare [4]. The results show that the too bright or too dark ambient light produce poor image quality. The results also indicate that the Concentrate-and-Scan method produces the best results at the same time. In 2015, Nguyen Thi Ngoc

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Quyen presented the optimum environmental light conditions with 2D indirect measuring system ≥ 300lux [5].

Research on the effects of background color: The backdrop is the term "back ground", attached to our actual example, the backdrop is the background behind the scanning object after scanning. With 3D scanning devices using light, the colors of the backdrop also have an important effect on the quality of scanning image. In 2000, new study by the creative team Adrian Hilton, Daniel Beresford, Thomas Gentils, Raymond Smith, Wei Sun and John Illingworth [6] was able to automatically reconstruct 3D models using blue backdrops. In 2012, the group of authors R.E. Sims, R. Marshall, D.E. Gyi, S.J. Summerskill, K. Cas [7] studied 3D TC2 human body scanners using white light and came to the conclusion that the optimal background color is black. In 2013, the study of underwater 3D scanners indicated that the darker surfaces (brown, gray and black) were of better quality than those of light-colored surfaces [8]. In 2015, the team of authors Dinu Dragan, Srdan Mihic, Zoran Anisic, Ivan Lukovicstudied decay after obtaining a cloud image without affecting the backdrop.In addition, some factors also have a very important influence on the quality of 3D human body scan images such as outdoor natural light, room light, temperature, humidity, standing posture. The appearance, color and texture of the object of the scan [9], etc. In the study presented in this paper, the authors focus on the influence of some elements of the lip scanning field such as backdrop color, scanning distance and illumination intensity of the light source in the indoor environment measurement. When using a 3d-scanner with structural light produced by the group of authors under conditions in Vietnam.

2. Experimental research

2.1. Research subjects

Subjects of the research include women aged 18÷23 years and with height from 1.5m to 1.7m.

Experimental equipment: The research uses the 3D body scanner based on the principle of structural light designed by Nguyen Thi Nhung and the designing team [1]. The device uses structural light with the principle of triangular measurement, gray encoding method, Optoma X321 projector, Camera Basec ace GigE, measuring chamber size 1.5 × 2.5m, measuring conditions with temperature of 25 ± 2 ° C, the humidity 65 ± 5%, the light intensity variation between 300-400lux, the distance variation from 80 to 100cm, experiment with two background colors: black and blue.

Specification of light intensity, temperature and humidity shown in Table 1.

Table 1. Specifications of the device measuring the intensity of light

Light intensity measuring device Extech	
Wind speed	
Scale	0,4 – 30 m/s
Resolution	0,1 m/s
Accuracy	± 3% FS
Flow	
Scale	0.01 - 1,908,400CFM
Resolution	(0.001 - 54,000 CMM) 0.001 CFM (CMM)
Light	
Scale	0 - 1860Fc (0 - 20,000Lux)
Resolution	0.1Fc (1Lux)
Accuracy	± (5% rdg + 8 digits)
Humidity	
Scale	10 - 95%RH
Resolution	0.1%RH
Accuracy	±4%RH of rdg
Temperature	
Scale	32 to 122°F (0 đến 50°C)
Resolution	0.1°
Accuracy	±2.5°F (1.2°C)

2.2. Research Methods

2.2.1. Determining the assessment criteria of 3D human body scan image quality

3D-scanned image data obtained by non-contact metering using structured light is a pixel cloud image. After the scanning process, in order to be able to exploit the data for research purposes and practical applications, the data needs to be further processed by image processing such as: measurement and calculation of human body size, 3D surface modeling, etc. To make the 3D image data good enough after scanning for subsequent image processing phases, 3D image scanned must meet the quality requirements as follows [10]:

a) 3D brightness rating criteria:

3D images obtained are required to ensure the brightness, they must not glare and they are not too dark or too bright, the borders of the image must be clear, not blurry, glare. In the study, we assessed the brightness requirement of the image according to the following criteria: The brightness in the scanning room must ensure brightness in accordance with TCVN 71141: 2008. in the ImageJ software to evaluate the grayscale value of the pixels. The brightness of the pixels is not too dark or too bright, and the gray-scale values of pixels need to reach a midtone of 64 to 192 [10].

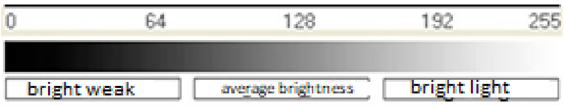

Fig 1. Diagram Histogram

These gray levels range from black to white with very smooth jumps, typically 256 different levels by standard. Since the human eye can only clearly distinguish itself from about 200 different gray levels, it is entirely possible to observe the continuous change of gray levels as shown in Figure 1.

b) Image Resolution Criteria:

3D scanned images obtained must be clear, not interfered by factors such as costume, hair ... At the same time to process the image on specialized software conveniently, with high speed and decreased storage capacity, in the study, we evaluated the resolution of the image according to the criteria: pixel density measured on image analysis software. Research results show that [11], to evaluate the scanned image quality, it is necessary to compare the actual number of scanned pixels with the theoretical pixel count. If the actual number of pixels of the image scanned is lower than the number of theoretical pixels scans will not be satisfied. With the same image area, the larger the number of pixels, the better the image quality. The pixel density in an image is used to evaluate the quality of the pixels and thus to represent the resolution of the image. The higher the resolution, the more information the image contains.

2.2.2. Research establishes measurement conditions

In parallel with our work on the 3D body scanner of structural light users, the authors [1] have calculated the scanning distance theory when the selected optical system is 93.3cm. This is the average of our research. The change in the value of scanning distance depends greatly on the height of the scan object, so to ensure the generality and accuracy of the experiment, we select the variation of the scanning distance value. 80 - 100cm.

Determining the conditions for measuring of light intensity of environment: In the study by Mohit Gupta, Qi Yin, Shree K.Nayar[10], we found that the measurement using the outdoors natural light is not suitable for human subjects with specific or non-dressed clothing therefore,we choose the measurement conditions in the measurement room with the source of light as artificial lighting. Based on Vietnamese standard 7114 - 2008 on the recommended light intensity, we provide reasonable laboratory conditions with a temperature of 25 ± 2 ° C, a standard moisture content of 65 ± 5% and the light intensity of the environment 300-400lux, using fluorescent lamps to provide light in the room.

Determine the background measurement conditions: Through the previous researches we found that the two most used background colors are black and blue. In this study, we used both background colors, conducted some experiments to select the optimal background color with the fabrication equipment.

2.2.3. Research, experimental design and experimental data processing

The research uses the two-element orthogonal experimental method to design the experiment, process and construct empirical regression equation, which aims to study the simultaneous effects of two environmental conditions on quality of the scan image [12].

Number of samples to be tested: use level 2 orthogonal planning for 2 influencing factors. Number of experiments: $N = 2k + n_0 + 2k = 2x2+2+2x2 = 10$ experiments [4]. Each test sample measures 3 times. Total sample $10 x 3 = 30$ samples. Of these, 2k is the number of experiments around the center, calculated as α = ± 1.41. The variability of the experimental elements and the experimental matrices is shown in Tables 2 and 3.

A method of optimizing a target based on the expected function method (group of analytical methods) was investigated by Harrington (1965), Gatza-Millan (1972) and Derringer and Suich (1980) study [13].

Design Expert 6.0 is used to process empirical data and visually display research results based on Harrington's orthogonal planning and one or multiple optimization algorithms.

In Table 3, Y is the average gray level calculated after the price change of two factors X_1 and X_2

Table 2. Variable ranges (real variables and coding variables) of the research elements

NB	Factors X_j	Encryption value				
		-1,41	-1	0	+1	+1,41
1	X_1 (cm)	75	80	90	100	105
2	X_2 (Lux)	280	300	350	400	420

Inside: *X_1 – Distance scanning (cm)*
X_2 – Light intensity (Lux)

Table 3. Experiment 2 matrix elements

No.	Encoding variable		Real variable		Y
	x_1	x_2	X_1	X_2	
1	-1	-1	80	300	178.5
2	+1	-1	100	300	195.9
3	-1	+1	80	400	185.8
4	+1	+1	100	400	202.2
5	-1,41	0	75	350	244.9
6	+1,41	0	105	350	179.6
7	0	-1,41	90	280	152.2
8	0	+1,41	90	420	209.1
9	0	0	90	350	169.4
10	0	0	90	350	168.2

Meshlab software is used to process and transcribe images (illustrated in Figures 2 and 3). Photographs obtained will be subject to interference due to environmental effects and measurement conditions. On the other hand, the scanner area of the scanner is not large, so it is necessary to divide the scan object into parts then multiply it. Therefore, a software to support editing is needed to have the most completely scanned image data. However, only the noise can be removed, the image is not allowed to change the structure, shape and size of the image.

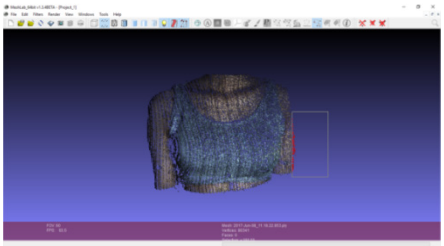

Fig 2. Noise interference on the Meshlab software

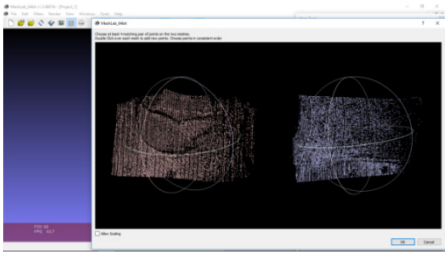

Fig 3. Manipulating images on the Meshlab software.

Fig. 4. Calculate the gray value on software ImageJ

ImageJ software and Histogram diagram are used to evaluate the quality of human scan image data as illustrated in Figure 4. After a complete scan of the image data, what we need to do is to evaluate the quality of scanned images. The visualization method may not be perfect when it comes to prove, as measured by the ImageJoy software, to give you the most specific rating.

2.3. Research results and discussion

2.3.1. Result of the selection of the background color of blood

The visual assessment and digitalization of the number of pixels obtained by data collection of the gray scale image scanning the body of a female student are shown in Figures 5a, 5b, 6 and 7.

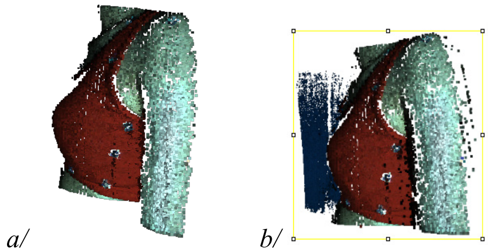

Fig. 5. Left chest scan image
a/ Blue background; b/ Black background

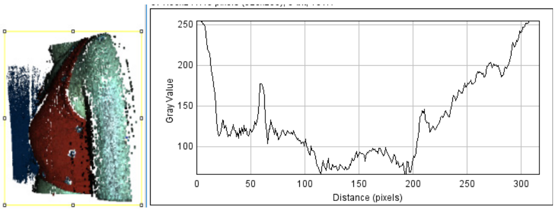

Fig. 6. Left chest scan image and gray level value chart for green background.

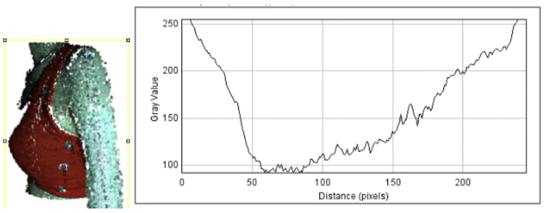

Fig. 7. Scanning of left chest and gray level chart for black background.

Reviews: The results are rated by grayscale histogram. The brightness of the image should not be too dark or too bright, but it should reach the mean (≈ 100-150).

By comparing the value of two graphs seen: With a blue background, the value is dark (<100), With black background, this value is very low. Therefore, there are more obtained points and these points are clearer (Figures 6 and 7). Results: Select black background.

2.3.2. The results of the influence of two factors, scanning distance and light intensity on the quality of the scaned image

The results of the gray-scale Y values of the 10 experimental designs in the experimental matrix investigating the simultaneous influence of two environmental conditions on 3D image quality are presented in Table 2. The illustrations of the grayscale distribution charts of each experimental design are shown in Figures 8 to 17.

Experiment 1: Scanning distance is 80cm, light intensity is 300lux in Figure 8.

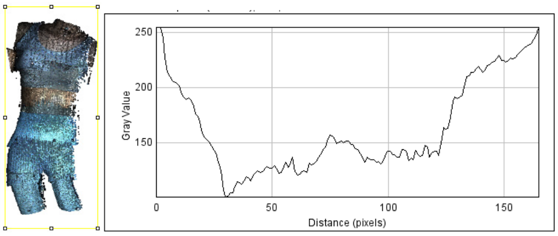

Fig. 8. Point cloud image and gray scale distribution graph. Distance is 80cm, light intensity is 300lux.

Experiment 2: Scanning distance is 100cm, light intensity is 300lux in Figure 9.

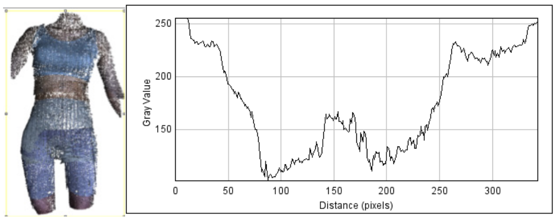

Fig. 9. Point cloud image and grayscale-scale graph. Distance is 100cm, light intensity is 300lux.

Experiment 3: Scanning distance 80cm, light intensity 400lux environment in Figure 10.

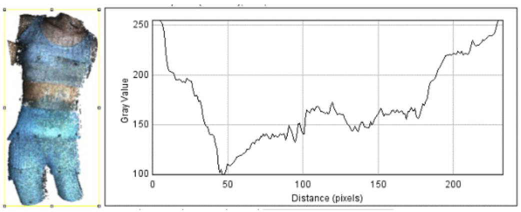

Fig. 10. Point cloud image and grayscale scale graph. Distance 80cm, light intensity 400lux.

Experiment 4: Scanning distance 100cm, light intensity 400lux environment in Figure 11.

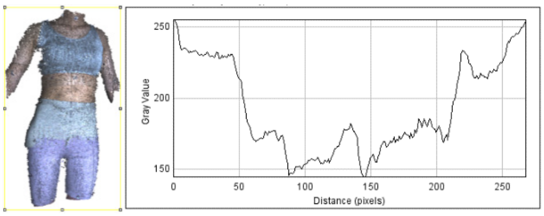

Fig. 11. Point cloud image and grayscale-scale graph. Distance 100cm, light intensity 400lux.

Experiment 5: Sweep 75cm; light intensity 350lux environment in Figure 12.

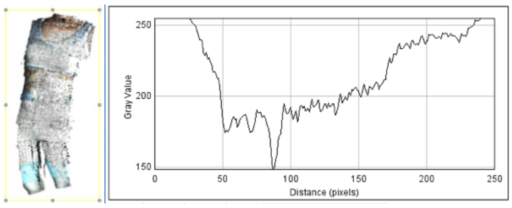

Fig. 12. Point cloud image and grayscale-scale graph. Sweep 75cm; light intensity 350lux.

Experiment 6: Scanning distance 105cm, light intensity 350lux in Figure 13.

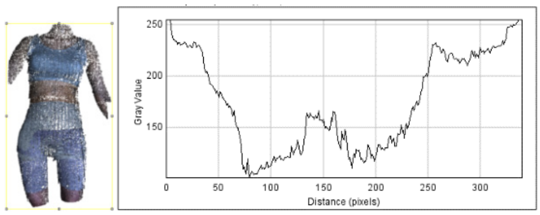

Fig. 13. Point cloud image and grayscale-scale graph. Distance 105cm, light intensity 350lux.

Experiment 7: Scanning distance of 90cm, intensity of light a 280lux field in Figure 14.

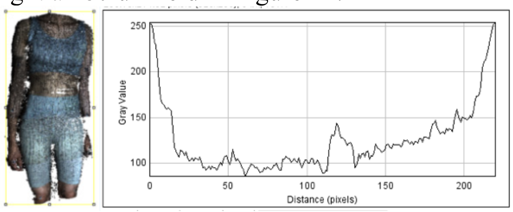

Fig. 14. Point cloud image and grayscale-scale graph. Distance of 90cm, intensity of light a 280lux.

Experiment 8: Scanning distance 90cm, light intensity 420lux environment in Figure 15.

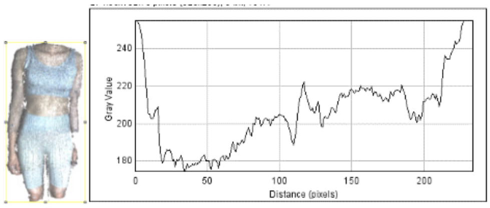

Fig. 15. Point cloud image and grayscale-scale graph. Distance 90cm, light intensity 420lux.

Experiment 9: Scanning distance 90cm, light intensity 350lux environment in Figure 16.

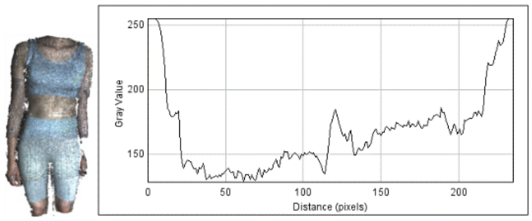

Fig. 16. Point cloud image and grayscale-scale graph. Distance 90cm, light intensity 350lux.

Experiment 10: Scanning distance 90cm, light intensity 350lux environment in Figure 17.

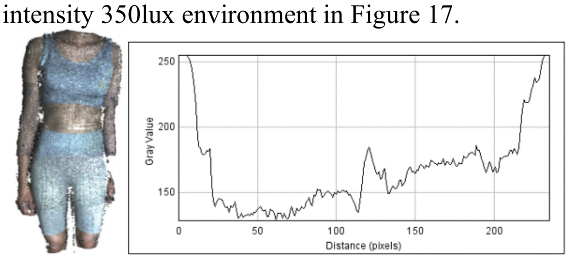

Fig. 17. Point cloud image and grayscale-scale graph. Distance 90cm, light intensity 350lux.

Table 4. Results of ANOVA analysis on the effect of weak conditions on the 3D image quality of the user body light scanned structural light

Total			Means		F
Source	**SS**	**df**	**Square**	**Value**	**Prob > F**
Block	27.20	1	27.20	1210.49	
Model	6100.87	7	871.55	1776.63	0.022
A	1279.17	1	1279.17	197.05	0.015
B	141.88	1	141.88	2622.09	0.045
A^2	1887.90	1	1887.90	195.03	0.012
B^2	140.42	1	140.42	0.35	0.045
AB	**0.25**	**1**	**0.25**	**2762.74**	**0.661**
A^3	1989.17	1	1989.17	776.29	0.012
B^3	558.93	1	558.93		0.023
A^2B	**0.000**	**0**			
AB^2	**0.000**	**0**			
Error	0.72	1	0.72		
Total	6128.80	9			

Using Design Expert 6.0 software to process experimental results and construct experimental regression equation shows the simultaneous influence of two environmental conditions on image quality of 3D human scan. The equation is as follows:

$$Y = 165.88 + 39.99X_1 - 13.32X_2 + 21.72X_1^2 + 5.92X_2^2 - 0.25X_1X_2 - 31.54X_1^3 + 16.72X_2^3.\ R^2 = 0.999.$$

Correlation coefficient $R^2 = 0.999$ shows a high correlation between Y and two variables X_1 and X_2. The results of ANOVA analysis on the effect of weak substrates on the quality of body image scanning of 3D human light structures are presented in Table 4.

From the results of ANOVA analysis on the effect of weak substrate conditions on the 3D body image scanning of the user light structure, we see that: The values of "*Prob> F*" below 0.0500 show that the elements X_1, X_2, X_{21}, X_{22}, X_{31}, X_{32} have an important influence on the Y function.The values of "Prob> F" greater than 0.1000 indicate that the interactions: $X_1.X_2$ have an effect but little influence on the Y function. The values of "Prob> F" equals 0 indicate the interactions: X_{21}. X_2, X_{22}. X_1 donot completely affect the Y function, so that the interaction pairs do not exist in the empirical regression equation.

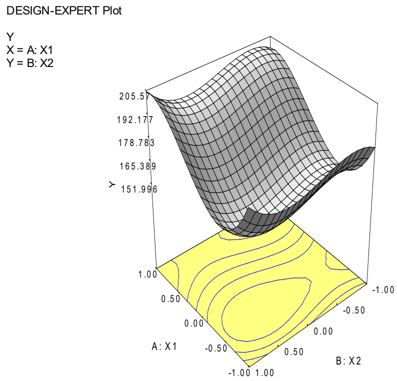

Fig. 18. 3D graphs on the relationship between condition factors and image quality.

2.3.3. The results of determining the optimum environmental conditions to ensure the best quality 3D human body scan

Using the Design Expert software, the research suggests that the Y function is limited to the gray from 64 to 192. Because the two-variable regression is a complex, nonlinear function of the variable domain of Elements, there is not just only an optimal one. To ensure the best scan quality, we in fact have identified 10 optimal options corresponding grayscale values of different scanned images which is shown in Table 5.

Reviews: The greater the scanning distance is, the wider the scanning field is, the fewer sweeps are the more accurate the imaging process is. But if the scanning field is too large, the resulting image will be blurry and likely to cause interference. The greater the intensity of light, scanned images get glare-prone, hard to see. In contrast the smaller the light intensity, the darker the scanned images get. It is also difficult to observe and evaluate image quality. With the scanning equipment and the scanning object are female students aged from 18 to 25, the optimal values of two scan distance parameters and corresponding intensity of light include: The optimal scanning distance is from 83.4 to 94.9 cm. Environmental light intensity in the range of 300.5 to pros to 388 Lux.

Table 5. The value of the coded variable and the real variable of the influencing factors and the optimal value of the function Y

NB	Y	X_1		X_2	
		Encoding variable	real variable (cm)	Encoding variable	real variable (Lux)
1	174.5	0.14	91.4	-0.20	340
2	178.3	-0.97	80.3	-0.16	342
3	157.7	-0.52	84.8	0.82	391
4	154.8	-0.29	87.1	0.19	359.5
5	185.3	0.31	93.1	-0.82	309
6	187.5	0.49	94.9	0.76	388
7	161.1	-0.66	83.4	-0.23	338.5
8	164.7	-0.22	87.8	-0.53	323.5
9	161.2	-0.60	84	-0.89	305.5
10	171.6	0.07	90.7	-0.99	300.5

3. Conclusion

In this article, we point out that by controlling the scan distance, ambient light intensity, background color... The 3D scanning system works faster and more accurately during 3D scanning. In fact, through the empirical process, we find that there are problems arising between theory and experiment.In some cases, the experimental results differ from the optimal results in the computational calculus.In this study, the results between theoretical calculations and experimental deviation is negligible. The parameters of the optimum environmental conditions determined from the experiment include: Distance scanning: 90 cm, environmental light intensity: 350lux for 3D images. Using these parameters to scan the human body achieve the best quality. On the other hand, the results of the empirical study show that black-light absorption is much better than the blue backdrop. With a built-in scanner that includes a projector, a camera, a turntable, and a shaft for the camera and projector, it is possible to scan any object that matches the standard conditions.

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