INFLUENCES OF SURFACE PARAMETERS ON LASER 3D SCANNING

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Abstract:
The quality of 3D scanned data is influenced by many factors, such as scanned surface color, glossiness, geometry, ambient light, scanner resolution, proper selection of scanned segments, etc. Surface color and glossiness are important sources of errors, and this paper studies their effects on a specific commercial scanner. Preparatory phase of digitizing process includes selecting proper combination of scanner's sensor aperture and shutter time, depending on the characteristics of scanned surface. This paper investigates a relationship between the color of scanned surface, the glossiness of scanned surface and the 3D laser scanning quality.

Keywords: 3D Laser Scanning, Surface Parameters, Color, Glossiness

1. INTRODUCTION

3D scanner is a device that collects data about a shape of real-world objects, in order to construct digital, three dimensional models. The non-contact active 3D scanners available today include time-of-flight 3D laser scanners, triangulation 3D laser scanners, structured-light (projected pattern) 3D scanners and modulated light 3D scanners. All these optical technologies used in 3D scanners encounter difficulties with shiny or transparent objects. To enable scanning of such objects, the scanned surface is usually covered with a thin layer of a powder that improves light reflection back to the scanner.

One of the popular low-end 3D scanners is shown in Figure 1. Its declared measurement uncertainty is 0.12 mm, and it is shipped with rather simple scanning software.

Fig. 1: Desktop laser 3D scanner NextEngine

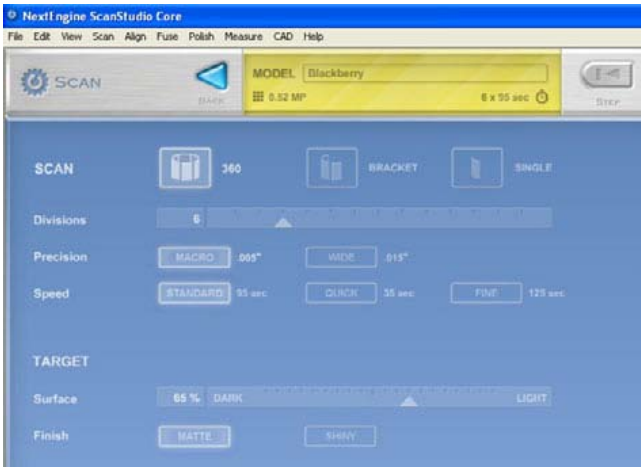


Fig. 2: Scanning software NextEngine ScanStudio v.1.6.0

The scanning is usually performed in segments, since no scanner can collect data in a single step. The objective is to obtain the desired scan with as little steps as possible.

Similarly to digital photography, where user has to choose the appropriate combination of aperture, exposure and shutter time, the 3D scanner user has an opportunity to adjust scanning parameters in order to collect the most accurate 3D data. The software presented here offers user an opportunity to choose between "matte" and "shiny" surface, and color between "dark" and "light". This choice is not always too intuitive and has a strong influence on scanning result, especially in terms of time needed. For example, it is not always obvious whether red is "darker" than green, or blue is "lighter" than gray.

This research was conducted in order to speed-up the procedure of setting these parameters for different scanned surfaces.

2. RELATED WORKS

Voisin et al. in [1] studied ambient light influence for 3D scanners based on structured light. They showed that ambient light can introduce errors into scanned data from most commercial 3D scanners based on projected patterns and structured lighting. They also proposed a physical explanation for the systematic error observed from colored patches.

Voegtle et al. in [2] studied influence of different realistic object materials and object colors on the measurements of terrestrial laser scanners. They showed that gray scaled test plates have proven a significant dependence between the brightness of the scanned object and the obtained accuracy. Another important result is the enormous difference between measurements at day and night-time (approx. a factor of 2).

Lichti and Harvey in [3] studied influence of reflecting surface material on time-of-flight laser scanner measurements. Their results showed no significant range errors due to differing material properties, but they did exhibit changes in range measurement distribution and return signal intensity.

Amiri Parian and Gruen in [4] performed an accuracy test of the point cloud of the laser scanner by using the laser's intensity image. They focused on other sources of errors, such as eccentricity of the scan center, collimation and horizontal axis error, tumbling error and resolution of horizontal and vertical rotation.

Boehler and Marbs in [5] investigated laser scanner accuracy through different test targets. They proposed the deviation of single points from the object's surface as an indication for the accuracy. They also studied influences of surface reflectivity, environmental conditions and edge effects.

Forest Collado in [6] described the 3D laser scanner calibration processes and methods, including the influence of surface optical properties. He showed that increase in light power can reduce the noise related to surface properties.

Vukašinović in [7] discussed the influence of surface topology on the accuracy of laser triangulation scanning results. He emphasized the scanning distance and scanning angle of impact laser beam as the most crucial interaction between the surface topology and scanning process.

3. EXPERIMENT

3.1 Equipment used

For the purpose of this research the NextEngine desktop laser 3D scanner (Fig.1) was used. The specifications of this scanner are listed in Table 1.

Table 1: NextEngine 3D scanner specifications.

Laser	Class 1M, 10 mW, solid state, 650 nm
Sensor	3.0 Mpixel CMOS
Resolution	400 DPI on target surface
Accuracy	± 0.005" (± 0.12 mm)

3.2 Target surfaces

Fig. 3: Samples used as scanning target surfaces

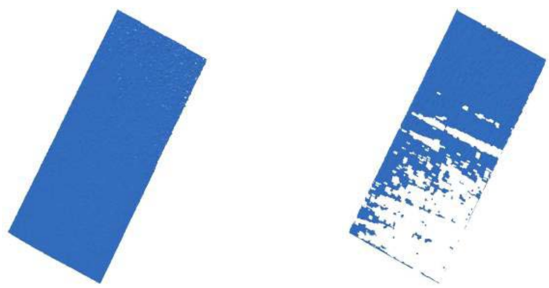
In order to have accurate colors of scanned target surfaces, standard samples of colored surfaces were used. The samples were manufactured by MACtac Europe S.A., Belgium (Fig.3), and they have RAL standard color codes. RAL is a color matching system used in Europe, mainly for varnish and powder coating, but also for graphics and CAD software. Table 2. summarizes RAL colors of samples used in this experiment. In order to relate the RAL color codes with common color models used in digital cameras (R:red, G:green, B:blue), the online color code calculator from [8] was used.

Table 2: RAL colors used, with RGB (0-255) codes [8].

RAL	MACCal color name	R	G	B
1023	9708-00 Matte Yellow 9809-09 Glossy Yellow	248	192	0
9003	9828-00 Matte White 9829-00 Glossy White	237	237	231
7042	9788-01 Matte Gray 9889-03 Glossy Gray	141	145	145
9005	9888-00 Matte Black 9889-00 Glossy Black	18	19	20
5017	9738-00 Matte Blue 9839-22 Glossy Blue	0	81	140
3020	9758-00 Matte Red 9859-04 Glossy Red	190	17	16
6029	9748-01 Matte Green 9849-10 Glossy Green	0	110	59

3.3 Data processing

The target surfaces with pairs of different colors (matte/glossy) were scanned at the same position, and with different settings of color (dark-light). The scanned point clouds were exported into OBJ data formats and trimmed to fit the same enclosed volume. To estimate the scanning quality, points were counted and compared to theoretically maximum number of points. Lower number of points referred to unsatisfactory color/surface settings. Figure 4 shows examples of scanned surfaces with satisfactory (a) and unsatisfactory (b) number of points. Due to poor software setting or glossy surface, some points are not scanned.



a) Satisfactory result (33300 points ≈ 99%) b) Unsatisfactory result (20000 points ≈ 60%)

Fig. 4: Scanned surfaces with different number of points

4. SCANNING RESULTS

Figures 5 to 11 show results of data analysis performed: they show how surface settings set in software (from 5:dark to 100:light) influence the number of points scanned. Each color was represented by matte and glossy sample, both having the same color, i.e. the same RAL code.

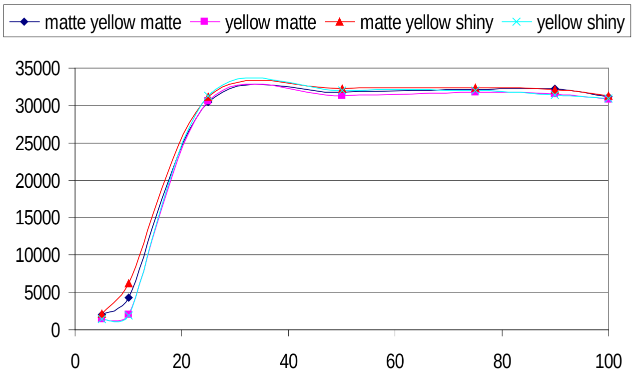


Fig. 5: Scanning results for yellow samples (RAL 1023)

Yellow or white surface scanning does not depend on surface glosiness. There are almost no differences wheteher surface is scanned with "matte" or "shiny" software setting. Fig. 5 shows that any color setting above 40 will give satisfactory result for yellow surface. Fig. 6 shows that any white surface can be succesfully scanned with color settings above 50.

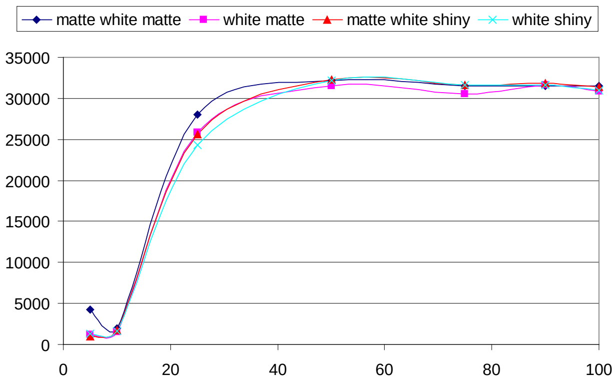


Fig. 6: Scanning results for white samples (RAL 9003)

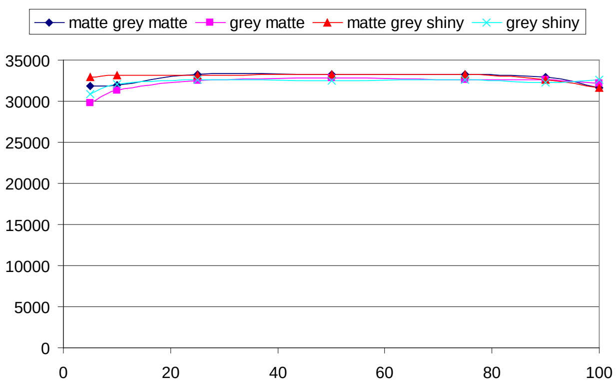


Fig. 7: Scanning results for gray samples (RAL 7042)

Gray surfaces show the best results for any software setting. When color setting in software is set between 20 and 80, gray surface shows no difference between matte or glossy samples, and "matte" or "shiny" software setting.

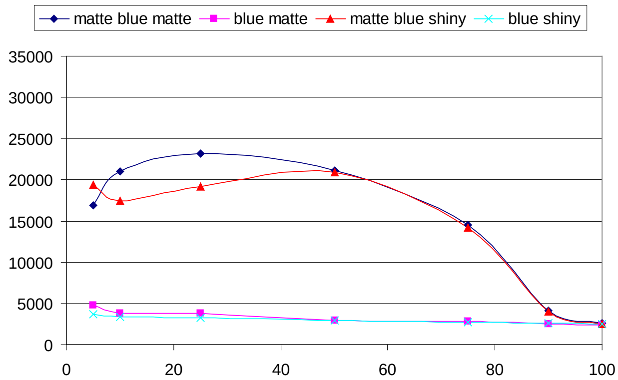


Fig. 8: Scanning results for black samples (RAL 9005)

Glossy black samples exhibit the poorest results. No software setting can give satisfactory result. Slightly better, but still unstaisfactory results are obtained when matte black samples are used. When software color setting is below 50, approximately 60% of points are acquired.

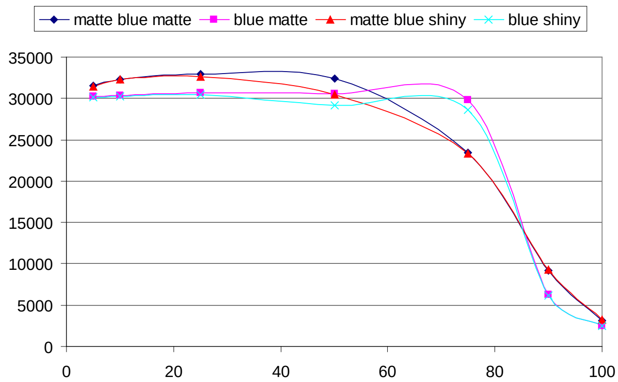


Fig. 9: Scanning results for blue samples (RAL 5017)

Red surfaces (Fig. 10) behave similarly to white or yellow surfaces; color should be set above 40. Glossy surfaces have slightly better results, and software glossiness does not influence the results.

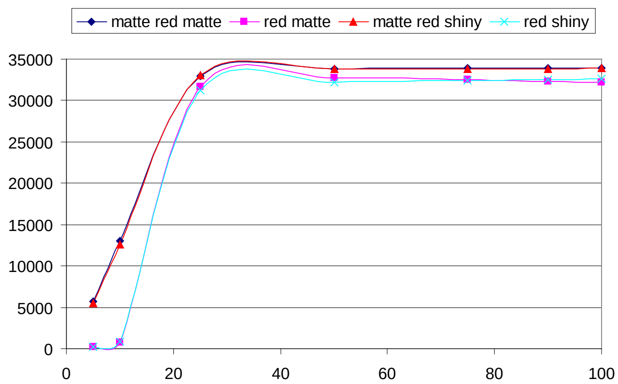


Fig. 10: Scanning results for red samples (RAL 3020)

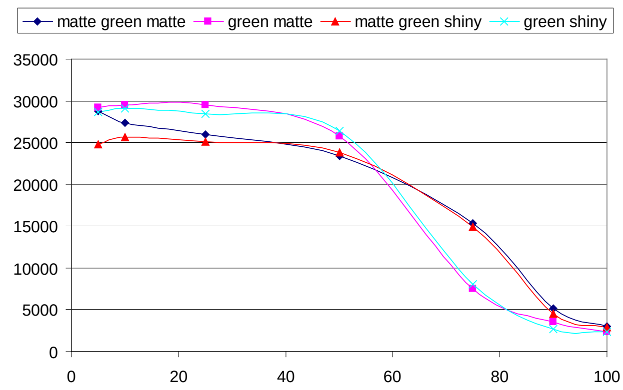


Fig. 11: Scanning results for green samples (RAL 6029)

Fig. 11 shows that green surfaces are harder to scan. Software color setting below 40 gives approximately 75% scanned points. The software glossiness setting has weak influence onto scanning result.

5. DISCUSSION ON RESULTS

The results showed that surface color has great influence on 3D scanning. To discuss on that, one should have in mind the component colors used by CMOS sensors; red, green and blue, as well as the color of laser slight used in scanner.

The best results are achieved with colors having strong red component (red, white and yellow from Table 2). These samples should be scanned with software color setting at the light side (above 40).

The poorest results are obtained with black and green surfaces. Both of these colors have low red component. On the contrary, the blue surface, which also have low red component, gives rather good results. Therefore, the red component cannot be the only criterion for scanning quality. It can be used to decide on software color setting; high red is "light" and low red is "dark".

Gray surface is the most appropriate for 3D scanning, and software color and glossiness setting does not influence results. Therefore, if the surface is to be sprayed, the spray color should be gray.

In order to compare the results for different colors, the common computer graphics equations for transformation of color into grayscale images are used. Two main equations are in common use, using intensity or luminance.

$$I = R/3 + G/3 + B/3 \quad (1)$$

$$Y = 0.299R + 0.587G + 0.114B \quad (2)$$

where:

- I is the grayscale intensity,
- Y is the grayscale component (luminance) in the YIQ color space, used in NTSC television standard, and
- R, G, B are component color levels for red, green and blue, respectively.

Table 3 shows the grayscale levels of colors used in this experiment, calculated using equations (1) and (2).

Table 3: Grayscale equivalent colors.

RAL	Color	I	Y
1023	Yellow	147	187
9003	White	235	236
7042	Gray	144	144
9005	Black	19	19
5017	Blue	74	64
3020	Red	74	69
6029	Green	56	71

The grayscale intensity for green is lower than for blue, which could explain the lower number of scanned points.

6. CONCLUSIONS

Previous investigation, presented in [9], investigated the influence of ambient light onto 3D scanning. The similar approach was used here to test the influence of surface parameters. Both researches showed that the gray surface is the most convenient color for 3D laser scanning.

This research showed that surfaces which have higher level of red component, such as white, yellow or red, give better scanning results, because this component correspond to the color of laser beam used in 3D scanner.

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