THE SOURCE OF UNCERTAINTY IN 3D LASER SCANNER

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ABSTRACT: 3D laser scanner become popular in manufacturing field because of its capability in measuring various characteristics of part and reverse engineering. It is found that laser scanner which categorize under non-contact method is less accurate compared to the contact method. This is due to the output quality that depending on digitizing points captured during scanning. These digitizing points are affected from extrinsic and intrinsic parameters. Some of the parameters for commercial lasers are already calibrated prior to delivery. In this paper, extrinsic parameters are discussed based on LC15 laser scanner with Metris scan 4.1 software. A suggestion on model of uncertainty is suggested based on propagation of uncertainty method align with the understanding of extrinsic scanning parameters.

KEYWORDS: 3D laser scanner, Coordinate Measuring Machine, CCD.

1.0   INTRODUCTION

The capability of non-contact method in facilitating manufacturing processes is able to improve the competitiveness of most manufacturing company. This is driven by digitizing technique of products which later can be manipulated for measurement and reverse engineering. In general, the advantage of 3D laser scanner are able to perform full 3D scan faster than the touch trigger probe although dealing with complex components. The non-contact method approach able to prevent possible deformation and scratches when deal with flexible or fragile materials. However, in the case of Coordinate Measuring Machine (CMM), laser scanner is at least one order of magnitude less accurate compare to contact method touch trigger probe (Feng, *et.al*., 2001).

Researchers are studying this issues which most of it focusing on

scanning paths and data manipulation of laser scanner. A different approached is studied by Mekid and Luna (2007), whereby they stated that digitizing parameters contribute by the manufacturer and user are directly affecting the accuracy of the laser scanner. This is also done by Gastel, *et.al*. (2009) which study on the parameters of angle, scan depth and thermal stability test. They found that these parameters are directly affecting the random and systematic errors. Mekid and Luna, (2007) divide digitizing parameters to two types that are extrinsic and intrinsic. Extrinsic parameters are parameters that can be controlled by user while intrinsic parameters are not accessible by user.

In this study, the author classified the digitizing parameters into three types which are easier to be identified. Intrinsic parameters are come from two sources that are; laser scanner and scan object characteristics. For laser scanner, intrinsic parameters is set and adjusted by manufacturer which some of the parameters is stated in the technical specification of the product. These parameters are already calibrated before laser scanner being used by users. For example, Metris the manufacturer of laser scanner model LC 15 have mention parameters of depth of view and stand of distance in their laser specifications. Non-contact method is known to be dependent on the quality of the reflection which is other types of intrinsic parameters. For example, color of scan object, edges and deep feature. These depended parameters give an option to the user in making planning and decision prior scanning. To overcome this issue, scanning technique can be used in minimizing the impact of intrinsic parameters from scan object characteristics. For example, the use of coating by using developer enables black and transparent objects to be detected by the laser sensor which introduced error.

In this paper, only extrinsic parameters for 3D laser scanner LC 15 manufactured by Metris are being considered. These extrinsic parameters are relying on Metris scan 4.1 software which facilitating the laser. Section 2 will explain about the source of uncertainty, Section 3 will discuss about uncertainty model suggested by the author and Conclusion is followed in recapitulate the findings.

2.0   UNCERTAINTY IN LASER SCANNER

Mekid and Luna, (2007) classified speckle noise, resolution, occlusion, projected angle, deep features and edges as intrinsic parameters. Where intensity, distance between stripes, environmental conditions, warm up, black and white, field of view and stand of distance as extrinsic parameters. Table 1 shows extrinsic parameters that suggested by the

author based on the Metris Scan 4.1 software. These parameters are additional sources that listed by Mekid and Luna, (2007) and able to be set by the user. Figure 1 shows the illustration of the 3D laser scanner, LC15 manufactured by Metris.

Table 1: Extrinsic Uncertainty Parameters

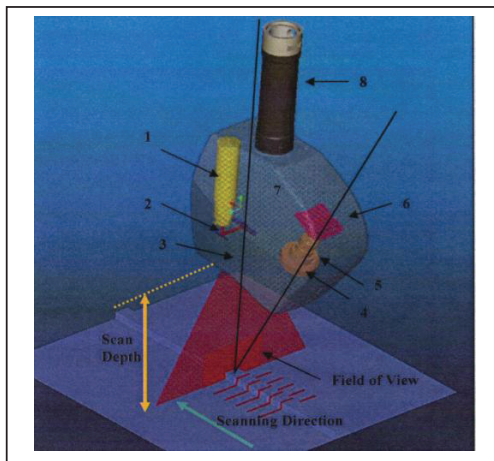| EXTRINSIC |
| --- |
| Distance between Points |
| Depth of Scan |
| Incident Angle |
| Laser Scanner Position |
| Distance between Stripes |
| Overlap between Laser Stripes |

Figure 1. The Fracture part for Metris LC15. (1) Laser Module, (2) Mirrors, (3) Lens, (4) Filter, (5) Lens, (6) CCD Detector, (7) Housing, (8) PH10 interface with CMM. Others labeling are shown as scan of depth and field of view that fall under laser parameters. The scanning direction, laser stripe and laser spot are just the properties of the laser scanner (Luna, 2005).

2.1   Distance between points

Distance between points can be set prior scanning as shown in Figure 2. The minimum value for distance between points is zero (0) mm. Although the distance is set at minimum value, digitizing resolution is still present and affecting the gap between points. The digitizing

resolution for Metris LC 15 is stated by Mekid and Luna, (2007) to be 20 μm and cannot be changed. Digitizing resolution plays a role in introducing error when the reflection points do not fall at the feature edges. This will cause either smaller or bigger size of scan objects.

2.2 Depth of Scan

Mekid and Luna, (2007) mentioned that the standoff distance is the distance between the output sources of the laser to the workpiece of the measurand. They grouped it as extrinsic parameters. The author believe that stand of distance is more appropriate to be selected as intrinsic parameter. This is because, by referring Figure 1, standoff distance is including the distance between the laser source to the laser lens and the distance between laser lens to the surface of the workpiece. These distances include the combination of intrinsic and extrinsic distances. In this study, the author suggested depth of scan parameter is more suitable to be investigated since the parameter is totally dependent on user setting thus,will be grouped under extrinsic parameters. With Metris 4.1, the depth of scan can be monitored from the camera preview dialog bog as shown in Figure 3.
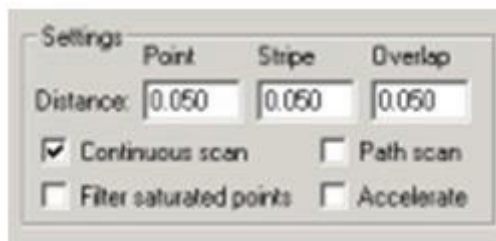

Figure 2. The interface input for the value of points, stripes and overlap in Metris Scan 4.1.

2.3 Incident Angle

Incident angle (α) is the angle of the laser from the laser planes to the laser position when perpendicular from the workpiece. The angle and the setting increment of the angle is totally depends on the touch probe interface which in this case the Renishaw PH10. Figures 4, illustrate the incident angle. The incident angle helps in capturing the side position or any hidden features that could not be captured from the vertical position of the workpiece. This eases the user by neglecting the requirement of adding handling factor to the measurement.
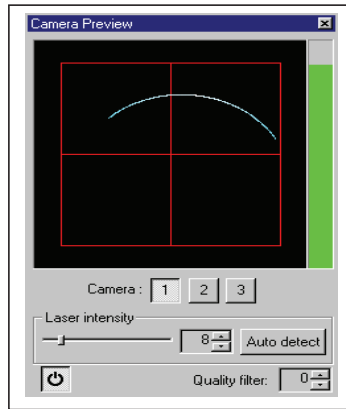
Figure 3. The camera preview dialog box for fast review on the distance of scanner and workpiece.
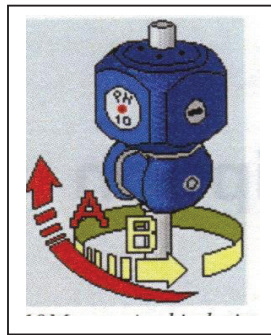

Figure 4. PH10 Orientation, A = Incident angle (α),
B = Scanner Position (δ)

2.4   Laser Scanner Position

Figure 5, shows three methods that can be used in manipulating the scanner position (δ) to perform a scanning. This method is one of the factors that studied in this project to investigate the probability of point detected at the edges of the workpiece. Although the author believed that the laser stripe and digitizing occlusions play an important role in detecting points especially at the edges, the scanner position can be used to manipulate these factors. It is believed, when angle is applied to the scanner position, the percentage of the laser scanner hit the edges of the component are higher. This is because, as shown in Figure 5(a) and Figure 5(c) the potential of the laser stripe miss the edges is high but in Figure 5(b), the percentage is minimum because in angle position. In order words, it is a trade off factors that important to be investigated in order to achieve the accuracy.
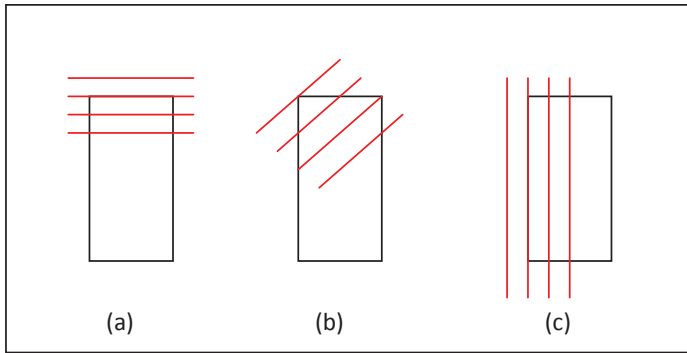
Figure 5. The laser stripe with different angle of laser scanner position. The angle is also depending on the interface of the laser scanner. In this project the interface of Renishaw PH10 is used. (a) The laser scanner in default position, 0° (b) The laser scanner at applied angle (c) The laser scanner at vertical position, 90°.

2.5   Distances between Stripes

The laser light that hit the negative lens will be diverges and forms the laser stripe. Laser stripe moves on the surface of the workpiece and points is collected along the stripe. The points are registered by the computer software in the form of cloud of points. This process is repeated based on the user input in the scan window setting to obtain the desired surface scan as shown in Figure 2.

The setting by the user will determine the quality of the scan surface. Figure 6 represents an example of scanning setting of the distances between stripes. This is because with smaller laser stripes distances, more points can be acquired. The vise versa will happen when the distances of stripes are increased. A close gap between distances will cause the increment of scanning time and slow speed scanning. Besides that, the distance between stripes can contribute to the detection of edges features. For example, when the distances are small, the potential in detecting the edges of a feature is grater than the use of bigger distances of stripe setting. There should be a trade off in setting the distance between stripes when deal with the surface to scan and features that required.
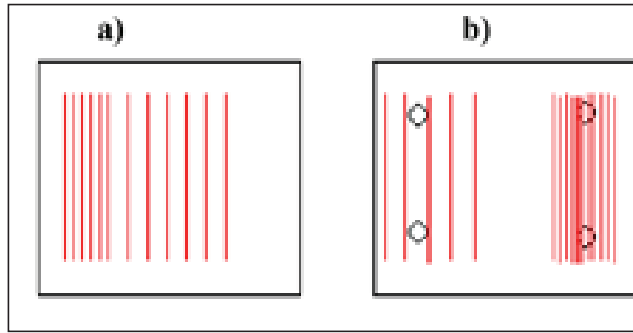
Figure 6. (a) When deal with a plain surface without any features on it, the distances between stripes can be increase for fast inspection. (b) The stripes between distances can be reduced for features scanning to obtain the accuracy in inspection.

2.6 Overlap between Laser Stripes

The overlap means the coincident between laser stripes in time during scanning. When the path of the scanning direction is determined by the user after selecting the area needed to be scan as illustrated in Figure 7, the overlap setting will determine the distances that required for the stripe to be overlap between one another. This will cause the volume of points increase at the area of intersection. This parameter is useful when certain feature is required to be in details.
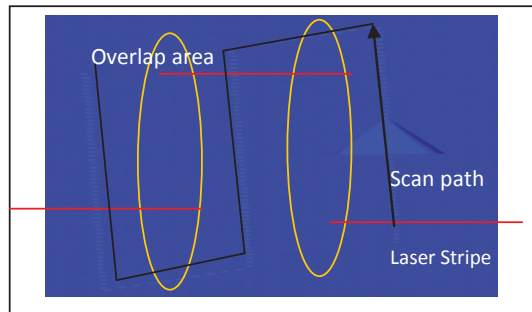

Figure 7: The scanning path of laser scanner and the overlap area. The overlap area is used to obtain the details in a certain scanning area.

3.0 MODEL OF UNCERTAINTY

Based on the discussion in Chapter 2, by adding these parameters the model of uncertainty can be obtained by using the additive property for propagation of errors as shown in Equation 1 that suggested by the author.

$$\delta = \sqrt{U^2{}_{\alpha_1} + U^2{}_\delta + U^2{}_{strp} + U^2{}_d + U^2{}_p + U^2{}_o}$$

(1)

Where δ = model of uncertainty, $\alpha1$ = incident angle, δ = scanner position, strp = distances between stripes, d = scan depth, p = distances between points, o = overlap between laser stripes.

Table 2 can be used to understand the effect of these parameters in measurement. Based on the results, Figure 8, shows the effect of these parameters during the calibration of laser scanner LC 15 by using a ceramic calibration sphere size of 15.014 mm. It shown that when the incident angle is increased, the standard deviation of the sphere measurement is at high level. Further discussion on the effects of these parameters in real measurement situation can be found in Kamil, S. and Mekid, (2009).

Table 2: Calibration result for Laser scanner at different angle.

| Run	Incident Angle, α, (°)	Scanner Position, δ, (°)	Std (μm)	Range (μm)
1	0.00	0.00	2.3	0.022
2	0.00	22.50	2.4	0.021
3	0.00	45.00	2.5	0.017
4	0.00	67.50	2.3	0.02
5	0.00	90.00	2.4	0.018
6	7.50	0.00	2.4	0.019
7	7.50	22.50	2.4	0.023
8	7.50	45.00	2.3	0.023
9	7.50	67.50	2.4	0.018
10	7.50	90.00	2.3	0.018
11	15.00	0.00	2.6	0.022
12	15.00	22.50	2.4	0.019
13	15.00	45.00	2.6	0.027
14	15.00	67.50	2.5	0.019
15	15.00	90.00	2.4	0.026
16	22.50	0.00	2.7	0.027
17	22.50	22.50	2.4	0.019
18	22.50	45.00	2.7	0.025
19	22.50	67.50	2.6	0.019
20	22.50	90.00	2.6	0.024
21	30.00	0.00	2.6	0.025
22	30.00	22.50	2.5	0.021
23	30.00	45.00	2.5	0.021
24	30.00	67.50	2.6	0.016
25	30.00	90.00	2.7	0.021
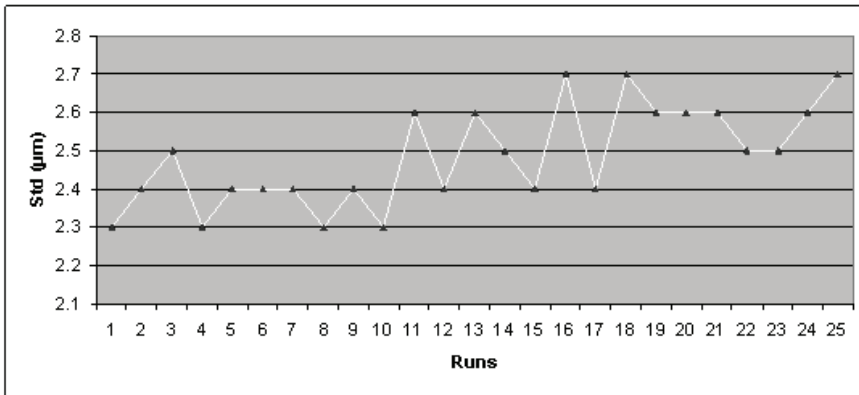
Figure 8. The standard deviation value for the laser scanner for each calibration at different angle.

4.0   CONCLUSION

Non-contact methods are widely used in industries especially laser scanner because of the advantages against contact methods. It has faster data collection, no deflection contact with measurand and able to produce 3D object for reverse engineering. However, it has lower accuracy compared to contact method. In this paper, discussion have been done in encompass the extrinsic parameters that contribute the level of laser scanner accuracy. It is found that incident angle plays an important role in determining the accuracy of the laser scanner although there will be other factors effecting it. In overview, the other factors are contributed from CMM, the complexity form of the workpiece and condition of the environment while the device is in used. A proper selection of parameters when using laser scanner LC15 is essential in producing better accuracy.

5.0   REFERENCES

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