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Development of Structured Light 3D Scanner Based on Image Processing

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Abstract

3D scanners are needed in various fields, and their usage range is greatly expanded. In particular, it is being used to reduce costs at various stages during product development and production. Now, the importance of quality inspection in the manufacturing industry is increasing. Structured optical system applied in this study is suitable for measuring high precision of mold, press work, precision products, etc. and economical and effective 3D scanning system for measuring inspection in manufacturing industry can be implemented.

We developed Structured light 3D scanner which can measure high precision by using Digital Light Processing (DLP) projector and camera.

In this paper, 3D image scanner based on structured optical system can realize 3D scanning system economically and effectively when measuring inspection in the manufacturing industry.

Keywords: *Digital Light Processing, Structured light 3D scanner, MeshLab, SLS.*

1. INTRODUCTION

With the development of computers, 3D scanners are needed in various fields, and their usage range is very wide. Especially, 3D scanners have been used for investment and research in order to shorten the manufacturing time of the products in the industrial field, and they are also used to reduce costs at various stages during the development and mass production of the products [1]. In particular, 3D scanning is used in various industrial fields such as reverse design, measurement, inspection, content generation, and CAD / CAM. Due to advances in computing technology, scanning performance is increasing and is being used in various fields. In recent years, real-time scanning technology has been able to acquire more than a few frames per second data and easily acquire three-dimensional data by automated data processing it is rapidly developing [2]. The method of acquiring 3D shape information in the 3D scanning includes a contact-type method and a non-contact-type method [3]. The contact-type method is a method of obtaining three-dimensional point data by physically contacting the object directly by using the probe apparatus. However, because of the probe size,

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it is difficult to measure small space, and because it has to acquire data manually by touching, it takes time to measure compared to the non-contact method and acquires three-dimensional surface data it is difficult to do.

The contact method obtains three-dimensional data based on triangulation by acquiring image information from an image camera with a distorted pattern on the subject by examining the shape of the pattern on the subject. In recent years, non-contact type which can acquire high speed and three-dimensional shape information has been used in the industrial field. In order to acquire high-precision three-dimensional data of press moldings and molds in the manufacturing industry, it is necessary to use a high-precision, high-precision laser mode with high decomposition performance [1].

Therefore, this paper develops Structured light 3D scanner based on DLP (Digital Light Processing) projector and camera. The structured light method used in this paper is suitable for measuring high precision of molds, presses, precision products, etc., and it is possible to realize a system which can economically and effectively perform 3D scanning when measuring inspection in the manufacturing industry.

2. STRUCTURE OF STRUCTURED OPTICAL 3D SCANNER SYSTEM

In real-time scanning, a structured pattern is projected on a measurement object using an optical projection device, acquired through an imaging device, and then acquired image is analyzed to calculate three-dimensional data optical system. The structured optical system can acquire a large area of three-dimensional data at once and is suitable for use in real-time scanning of three-dimensional data while moving the scanner at high speed. The principle of distance measurement using the structured light method is shown in Fig. 1. A scanner of a structured optical system projects a specific pattern onto an object, grasps the shape of the pattern, and obtains three-dimensional information. The pattern used here is projected onto an object using a two-dimensional pattern. The camera position is set slightly to the side of the project, the line is recognized in the pattern [4], and the depth value of all pixels constituting the line is photo trigonometry.

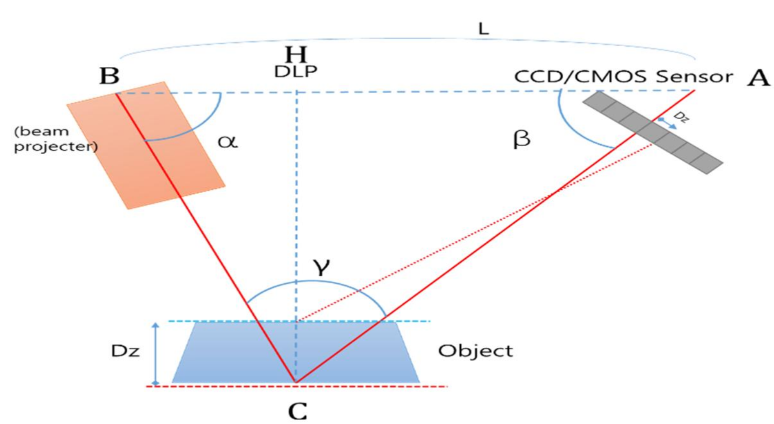

Figure 1. Principle of distance measurement using structured light method

Using the distance (L) between the DLP projector and the camera and the interior angles α and β on both sides, the distance of the HC can be checked by triangulation. The lengths of AC and BC are obtained based on law of sines. The following expression is equivalent to (1).
AC and BC lengths,

$$AC = \frac{AB \cdot \sin\beta}{\sin\gamma}, \quad BC = \frac{AB \cdot \sin\alpha}{\sin\gamma} \tag{1}$$

Therefore, $HC = AC \cdot \sin\alpha$ or $HC = BC \cdot \sin\beta$ can be obtained from (1).

4.1 Structured Optical 3D Scanner Device Configuration

The structured light technique is superior in depth accuracy, resolution and speed to different 3D measurement techniques such as stereoscopic vision or laser triangulation. Stereoscopic vision has the disadvantage that the algorithm is complex, and laser triangulation requires moving objects. However, the structural light utilized in this study does not have these limitations.

As shown in Fig. 2, the structured optical 3D scanner is composed of a DLP projector for projecting a pattern on a subject and a camera for capturing pattern image information illuminated on the subject. The performance of the PH550 DLP projector and oCam-5CRO-U camera are as follows.

- PH550 DLP: projector type DLP, projector resolution WXGA (1280x720) aspect ratio 16: 9
- oCam-5CRO-U: OmniVision OV5640 CMOS Image Sensor, Max 2592 (H) x 1944 (V) pixels @7.5, 3.75 fps

Figure 2. PH550 DLP Projectors (a), oCam-5CRO-U (b)

4.2 Structured Optical 3D Scanner Software

The image data captured by the hardware device is analyzed by software to generate three-dimensional data. The software consists of a 3D scanner calibration module, a structured light pattern repeat imaging module, and an object junction module. In order to calibrate the position and angle of the scanner devices, 3D scanner calibration was applied to correct the projection position of the projector and the camera angle using a marker based image processing technique. Obtain accurate object distortion data using a plurality of patterns for accuracy of object scanning, find matching points of objects to match objects, and match objects to complete one scan object.

The finished data was converted to surface data using point data and Meshlab was used for alignment, registration, and editing. Mesh Lab is an open source system that processes and edits 3D triangular meshes. It is a set of tools for mesh editing, cleaning, healing, inspection, rendering, and transformation [5].

Figure 3 is a software block diagram that allows scanning using structured light.

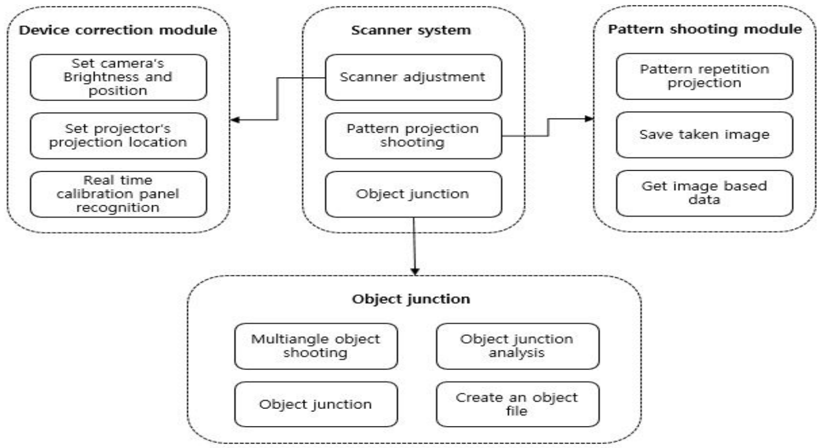

Figure 3. Structured optical scanning software block diagram

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3. THE PROPOSED STRUCTURED OPTICAL 3D SCANNER SYSTEM

In this study, beam project and camera are used to develop 3D scanner of structured optical system. Figure 4 below shows the process of creating a camera and projector layout environment before using the 3D scanner.

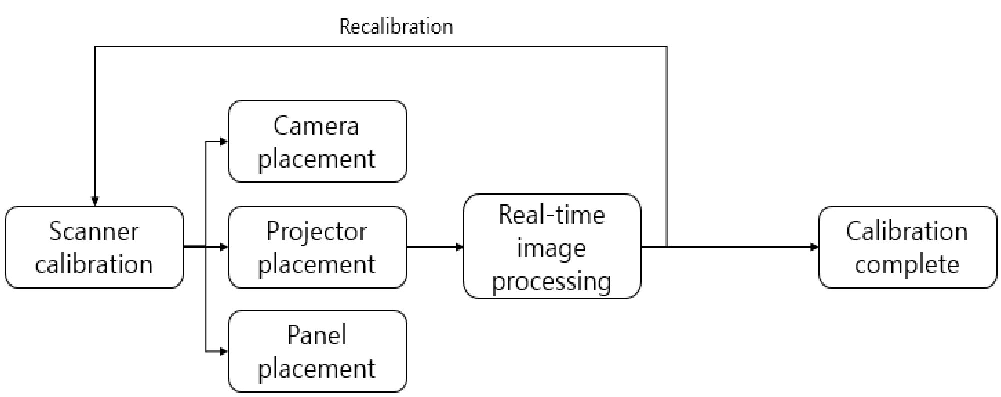


Figure 4. Scanner Calibration Process

To use the 3D scanner, adjust the position of the projector and the camera, and use the calibration panel to construct the usage environment.

After that, the pattern image is projected on the panel by the projector and then the real time photographing is carried out by the camera. Find the markers on the calibration panel among the images shot by the camera, extract the feature points as shown in Fig. 5, determine the projection position of the projector, check the position and angle of the devices, and proceed with the calibration.

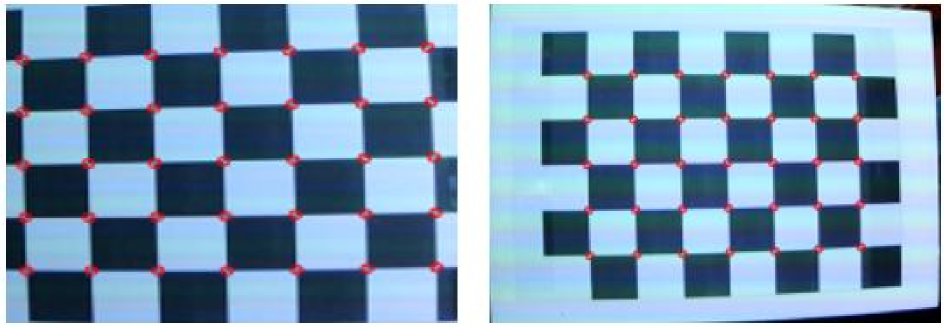


Figure 5. Capture and extract markers for calibration

4.3 Scan pattern projection objects

After the scanner is calibrated, the pattern is projected using the projector, and then the camera is photographed by pattern to acquire object data. As shown in Fig. 6 by projecting a pattern using a projector, the shape of the object is determined by photographing the distortion of the pattern due to the presence of the object. In this R&D process, the projector and the camera are calibrated by shooting at least three calibration markers.

The scanning software can check the three-dimensional area of the calibration value. Figure 6 extracts the black and white markers in the calibration step, extracts the corner positions and the number of the markers, and calibrates by comparing the image information entered with the calibration marker and the camera. Finally, to confirm the calibration, you can check the calibrated calibration plate as shown in Fig. 7.

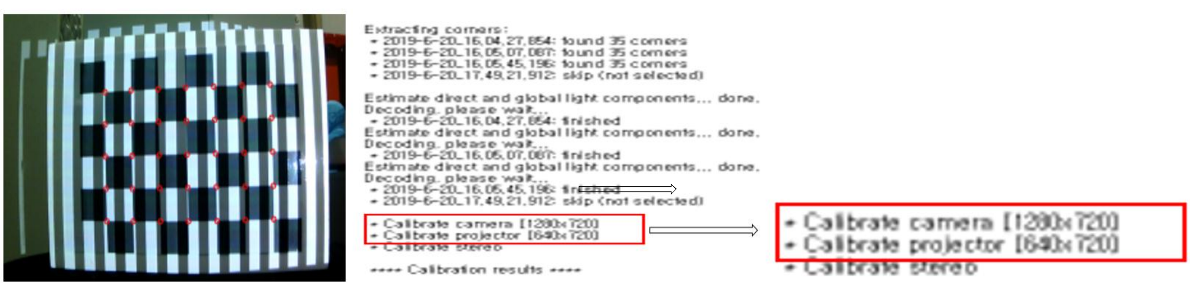


Figure 6. Black and white marker extraction from the calibration processor and scanner calibration

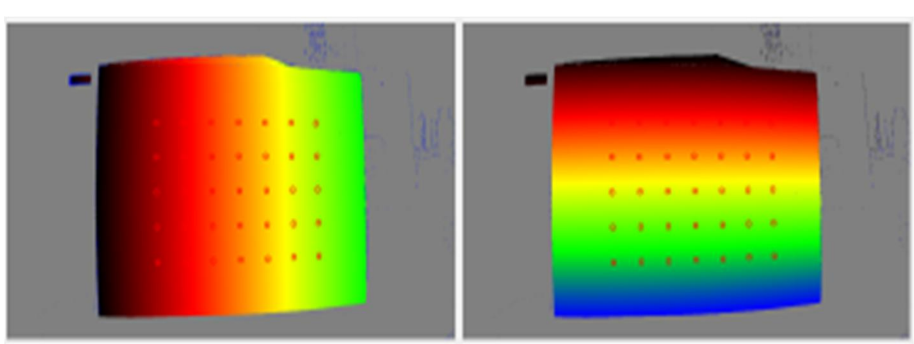


Figure 7. Corrected value after calibration

Figure 8 shows the pattern projection object shooting process. The structural optical system 3-D scanning of car press works was carried out in the form of Fig. 8.

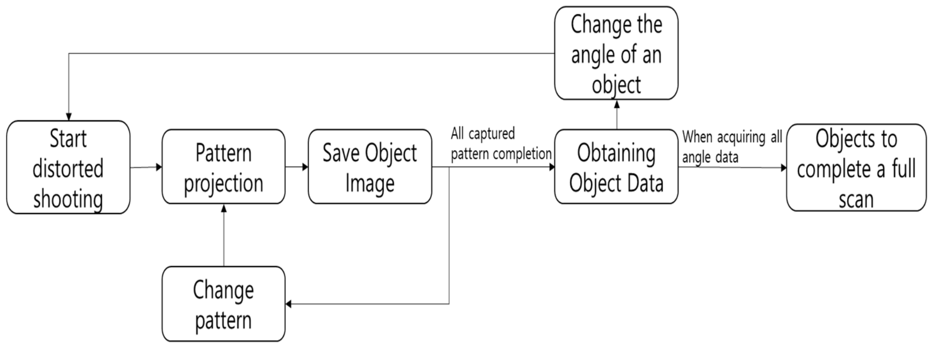
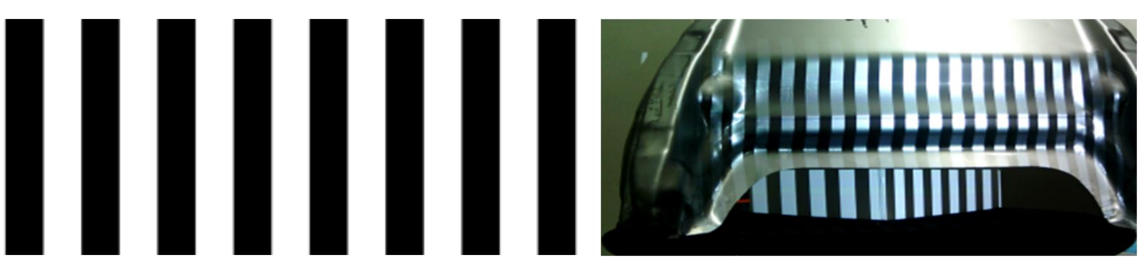


Figure 8. Pattern projection object shooting process

Patterns are all rectangular or striped and define the shape of the object by comparing the degree of distortion caused by the object with the original pattern. As shown in Fig. 9, the distortion of a specific part of the existing image can be confirmed. Such distortion photographing is repeated for each pattern through the process as shown in Fig. 10 to obtain object data of the surface on which the pattern is projected. After the data acquisition, the object is rotated to obtain the entire object data, and the shooting is repeated.

Figure 9. Structure of car press parts 3D scanning by optical method



(a) Original pattern image (b) Pattern distortion point through projection

Figure 10. Pattern distortion point through projection

4. RESULT

Structure scanning to perform 3D scanning, object scanning is performed by pattern projection using a calibrated scanner. Repeated pattern projection photography using multiple patterns is performed to acquire cross-sectional data of an object, and repeated photography is performed for each angle to acquire the entire data of the object.

A total of 42 patterns are used in this paper. In order to improve the precision of object scanning effectively, it is possible to obtain a concrete object shape by repeating shooting using various patterns. For object shooting, place the object at the position where calibration is finished as shown in Fig. 11. When placing objects, the proofing panel is removed and the projector can project the entire front.

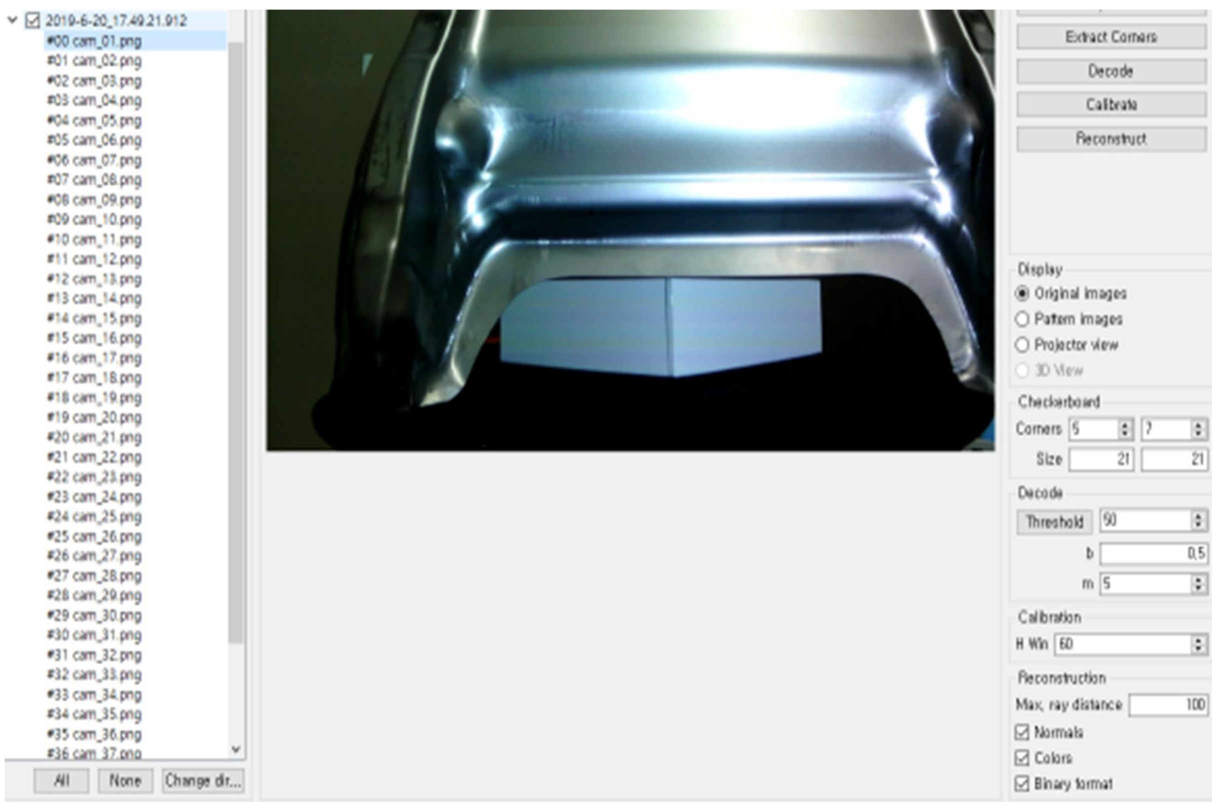


Figure 11. 3D Scanning of Automotive Press Parts

Pattern projection and image capture after completion of the iteration process, the program will acquire the cross-sectional data of the scanned object as shown in Fig. 12.

Thereafter, it proceeds to repeat the cross section scan by angle for whole object scan. As shown in Fig. 12, the area that can be scanned at once can scan an area of 382 mm in width and 227 mm in length. Have. However, the larger the size of a single area, the farther the DLP projector and the camera device are from the object, and the 3D scanning accuracy is lowered.

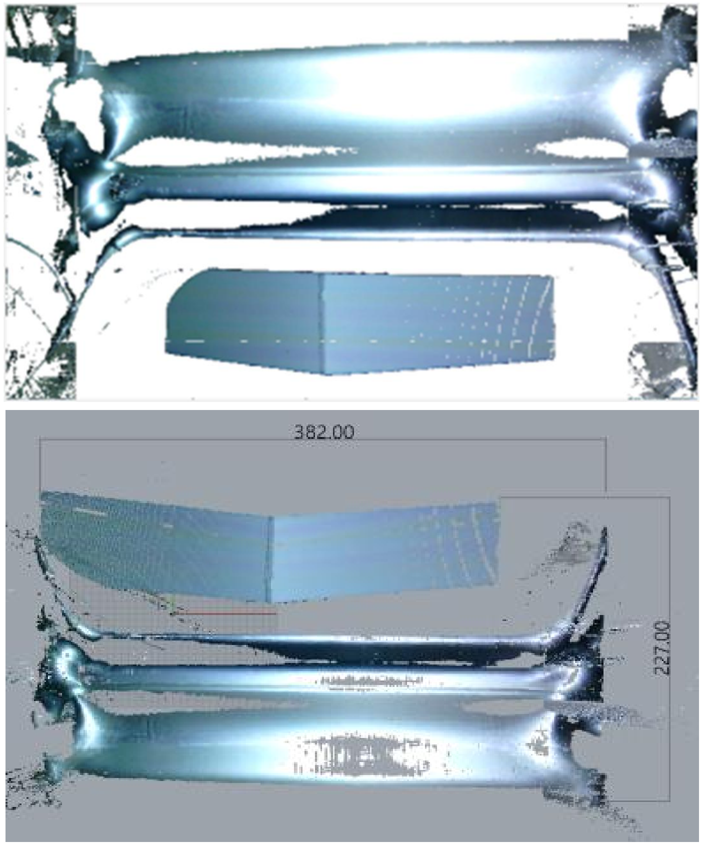


Figure 12. Car press parts 3D data (top), single scanning area (bottom)

Figure 13 shows the 3D scanning of actual car press parts using the structural light method proposed in this paper. Here, the three-dimensional data acquired through the 3D scanner and the three-dimensional design data for producing the product can be subjected to deviation analysis. To carry out the deviation analysis, use geomagic software of 3D system

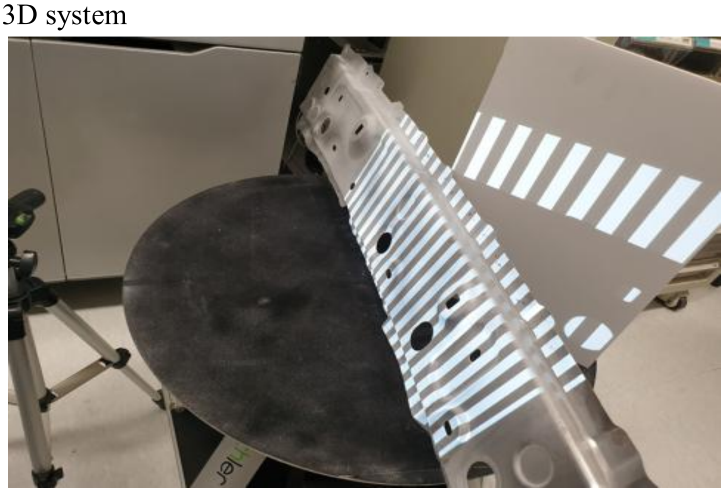


Figure 13. 3D Scanning of Press Parts of a Real Vehicle Using the Proposed Method

Geomagic software is a tool for sorting, editing, calibrating, and analyzing 3D data-only software. For deviation analysis, designed 3D design data is needed to produce 3D scan data and press in Fig. 14.

Analyzing the deviation using the geomagic tool, as shown in Fig. 15, provides a visual representation of the deviation of the design data and the produced product, and the magnitude of the deviation can be ascertained up to 10 microns.

In addition, the interval between the points is 0.2mm, and the resolution of the point cloud of the scanner can be confirmed.

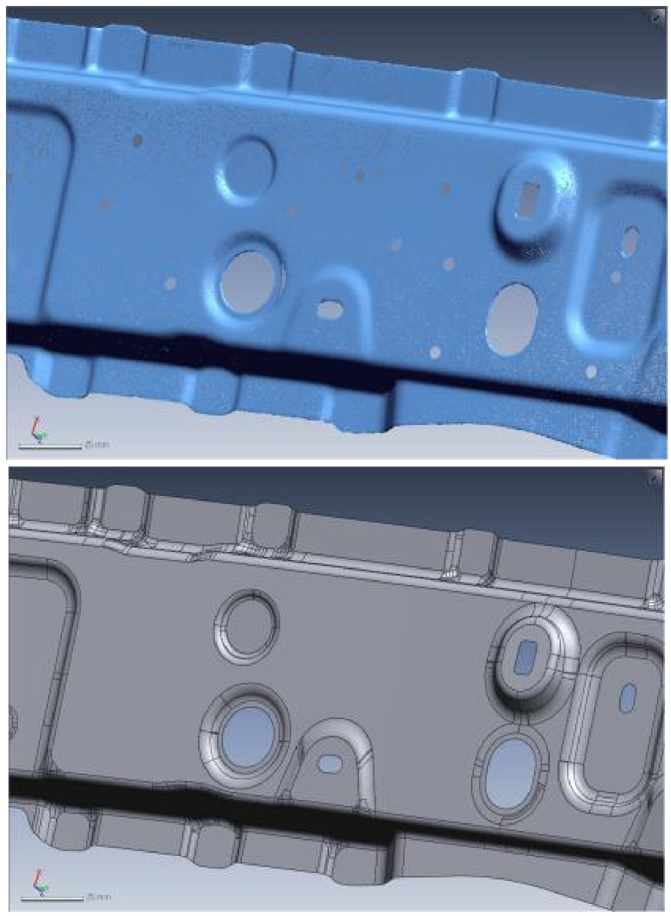


Figure 14. 3D scanned data of car press parts (top), 3D design data (bottom)

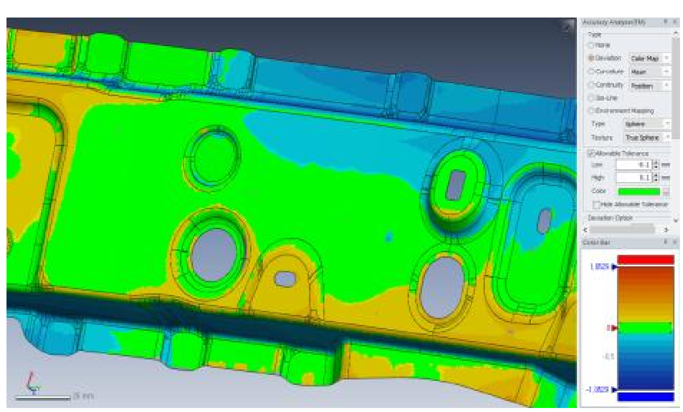


Figure 15. Detailed measurements of 3D scanned data on car press parts

5. CONCLUSION

With the advancement of manufacturing industry technology, the importance of precision mold technology and quality inspection is increasing day by day. In order to produce high quality products, quality inspection is required in several processes, but it is very important to first identify the intended range of deviation of design data and produced work pieces.

Structured optical 3D scanners are mostly foreign products, which makes it difficult for manufacturing industry companies to introduce them. Therefore, in this development, we developed a 3D scanner to acquire 3 - D data of products manufactured using structured light method and confirmed the performance through experiments.

Because the 3D scanner of structured light type uses HD class DLP projector and camera, 3D scanning speed is faster than the line laser method and the color information of object can be acquired. It has a high unit area that can be scanned 3D at a time because it is a method to scan the distorted pattern inspected by capturing an image in pixel unit and reconstructing depth information. However, in the case of structured optical system, 3D scanning is difficult in the case of objects with high reflectivity or black objects, and in order to be introduced into the manufacturing process, instantaneous deviation analysis" can be performed in 3D scanning speed and manufacturing process needs to be.

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