3D scanner's measurement path establishment automation by robot simulator

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Abstract: Recently, optical 3D scanners are frequently used for inspection of parts, assembly and manufacturing tooling. One of the advantages is being able to measure a large area fast and accurately. Owing to recent advances in high-resolution image sensing technology, high power illumination technology, and high speed microprocessors, the accuracy and resolution of optical 3D scanners are being improved rapidly.

In order to measure the entire geometry of objects, multiple scans have to be performed in various setups by moving either the objects or the scanner. This paper introduces novel methods to measure the entire geometry of objects by automatically changing the setups and then aligning the scanned data in a single coordinate system.

Keywords: automation, measurement, scanner, robot simulator, alignment, inspection

1. INTRODUCTION

Due to the competitive market environment, the importance of manufacturing quality is highly emphasized more than ever. The inspection of manufacturing tooling, parts, and assembly is one of the key elements of achieving high quality products.

Because of recent improvements in optical 3D measurement technology, the speed, accuracy, and resolution of 3D measurement has been improved drastically. However, there still remain research issues in the repeatability and reliability of 3D measurement.

This paper is focused on the automation of the inspection process with manipulators and optical 3D sensors in order to improve repeatability and reliability of dimensional inspection.

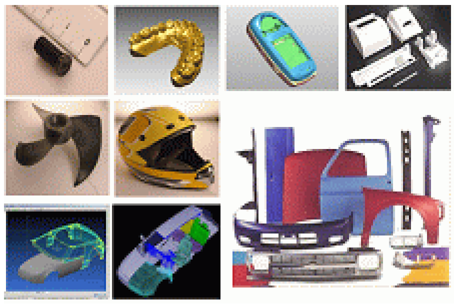

Fig.1 Application Example of Optical 3D Scanners

2. AUTOMATION OF MEASUREMENT

Optical 3D scanners now provide sufficiently accurate and high-resolution data for most inspection tasks in various manufacturing industry including automotive and electronics. Figure 1 illustrates some of application fields of optical 3D scanners.

Depending on the area of the scanning volume, the measurement accuracy varies from a few micrometers to a few dozens of micrometers. Up to a few millions of data point can be acquired in a single scan which takes a few seconds.

In this research, Rexcan from Solutionix Corp. is chosen as the optical 3D scanner in order to develop the method to automate the inspection process. Rexcan has advantages in the automation because of the following reasons. First, Rexcan uses white-light projection technology, and therefore, it provides accurate and high-resolution measurement data. Second, as the system is small in size and light in weight, the system can be easily attached to automation equipments such as robots.

2.1 Hardware

The proposed inspection system consists of two parts. One is the sensor to acquire the 3D coordinates of the object. The other is robot to move the sensor in various positions and directions.

In this system we used Rexcan 460 from Solutionix Corp. as a 3D acquisition sensor and FARAMAN AW1.0 manipulator from Samsung Mechatronics with MMC controller board as a sensor transport mechanism.

We used separate control PCs connected with RS-232 serial communication cable.

Table 1 Specification of robot.

Specification	FARAMAN AW1.0
Repeat Accuracy(mm)	± 0.1
DOF	6
Load Mess (kgf)	6
Power (KVA)	1.6
Weight(kg)	125
Arm Length(mm)	1339

Fig. 1 FARAMAN AW1.0.

Table 2 Specification of scanner.

Specification	REXCAN 460
Measurement Area(㎜^{2})	300 × 225
Scan Distance(㎜)	690
Scanner Type	Structured lighted method
Color	24Bit Gray
Measurement Time(sec)	5
Camera accuracy	1392 × 1040(pixels)
Power	Voltage(110~220v,50/60Mhz)
Light	Halogen Lamp
Temperature(℃)	18~30 (℃)
Weight(㎏)	4.4kg
Size(㎜^{3})	450 × 347.5 × 80

Fig. 2 Rexcan 460

2.2 Scanning process

We assume that CAD data exists for the parts to be inspected. First, CAD data is imported to the system. Then, the coordinates of CAD data and the coordinate of the robot are aligned to each other. The detailed process will be described in section 2.2.1.

Once the coordinate systems are aligned, the scanning path is designed by using a robot simulator. The detailed process will be described in section 2.2.2

Because the positional accuracy is not sufficiently enough for inspection, photogrammetry system is used to generate a marker frame on which scanning data can be aligned. The detailed process will be described in section 2.2.3.

Once the scan path and the marker frame are generated, the robot continues scanning according to the programmed path, and each scan data is aligned on the marker frame which is generated by photogrammetry system. Figure 3 illustrates the overall process of automatic scanning.

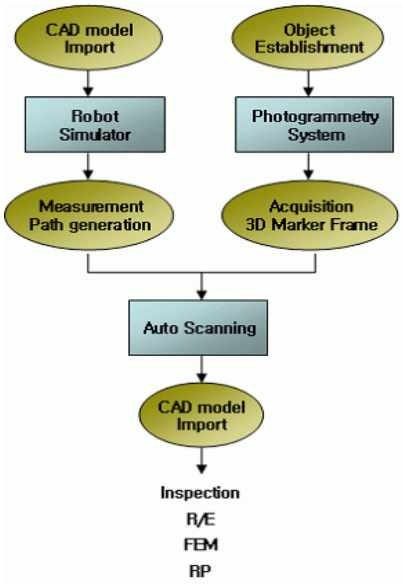

Fig. 3 Overview of the scanning process

2.2.1 Initial position setting

The alignment process is performed by the following two steps.

1. The relation between the sensor coordinate system and the robot coordinate system is calculated by using the dimensions of the sensor and the mount between the sensor and the robot.

2. The relation between the sensor coordinate system and the object coordinated system in CAD data is calculated by aligning the CAD data and a single scan data. When jigs are used, the scan data of jigs are measured by the sensor, and the relation between the coordinate system of jigs and the coordinate system of the sensor is used to calculate the relation between the coordinate system of sensor and the coordinate system of the scanning object.

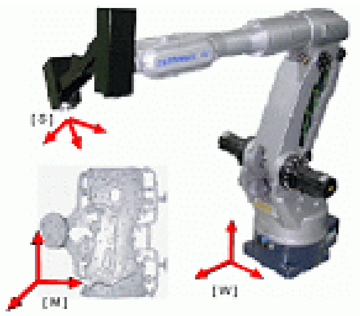

Fig. 4 Coordinate alignment of scanner, robot and object

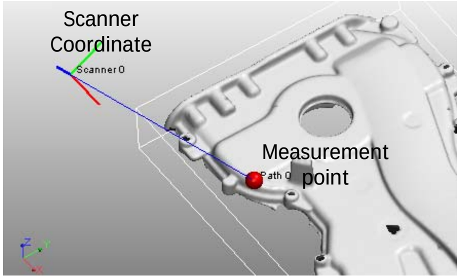

Fig. 5 Initial position setting

2.2.2 Measurement Path

Once CAD data is imported in the robot simulator, the region of object to be scanned is determined by the user as shown in Figure 6. Red spheres in the figure are the points that are input by the user. Because the relation between the coordinate system of CAD data and the coordinate system of sensor is pre-determined, the position and orientation of sensor to scan the point can be calculated.

Once the sensor position and orientation is determined for each measurement posture, then appropriate posture of robots are calculated by solving inverse kinematics of the robot. Because the generated robot path can produce interference with objects, the path is verified by using graphic simulation process.

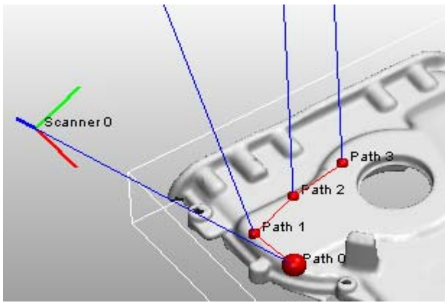

Fig. 6 Path generation using robot simulator

2.2.3 Marker Fame

Because the robot position is not sufficiently accurate, photogrammetry system is used to generate a reference on to which scan data can be aligned. Figure 7 illustrates the process of acquiring a marker frame by using photogrammetry system. First, circular markers are attached on the surface of the object. Then, multiple pictures are taken from various positions. By using the bundle-adjustment algorithm, three-dimensional positions of markers are calculated. The dimensional accuracy of the markers is less than 10 micrometers. The group of three-dimensional points is called a marker frame, and the scan data is accurately aligned to the marker frame.

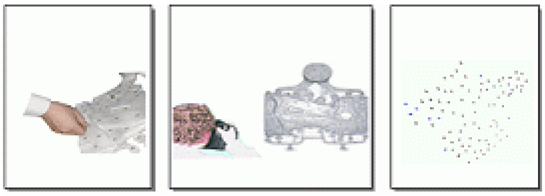

Fig. 7 Acquisition marker frame
By using photogrammetry system

2.2.4 Auto scanning

Once the measurement path and the marker frame are defined, then the robot moves the sensor according to the measurement path and scans the object. The scan data obtained by Rexcan has the marker position data as well as surface data. By using matching the marker position obtained by Rexcan and the marker frame obtained by the photogrammetry system, the scan data can be accurately aligned on the marker frame.

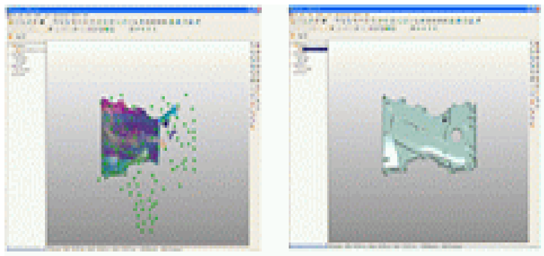

Fig. 8 Scanning and auto-alignment

3. IMPLEMENTATION

Figure 9 shows the hardware setup. Optical 3D sensor is attached to the robot and the sensor scans the object.

Fig. 9 Robot control and scanning

The software is implemented in Microsoft Windows environment. Figure 10 shows the user interface of the program that controls the robot.

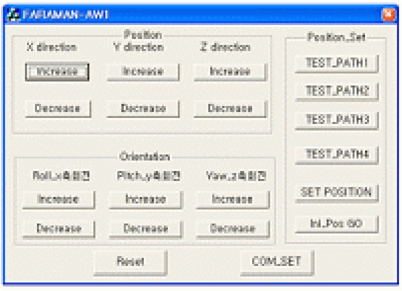

Fig. 10 Robot control program

Figure 11 and Figure 12 illustrates the scanning path and the sensor position respectively.

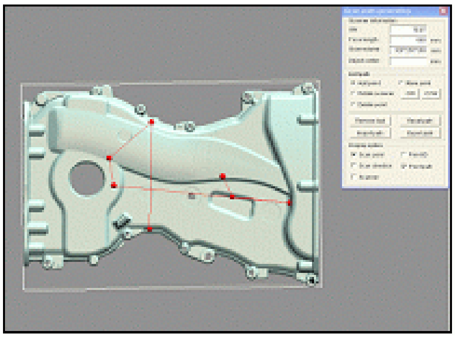

Fig. 11 Defining scanning path

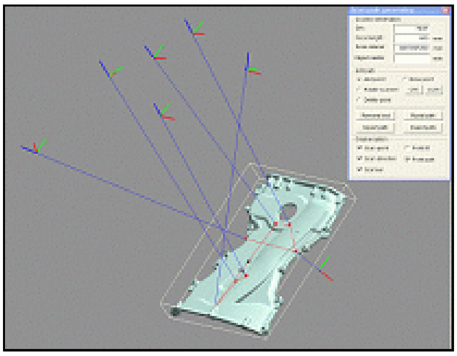

Fig. 12 Sensor position

Figure 12 illustrates the scan data acquired by the sensors in the position determined by the user.

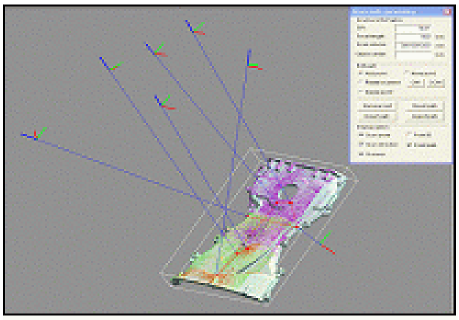

Fig. 13 Scan data acquired in various scanning position

4. CONCLUSION

In this paper, a method to automatically measure three -dimensional shape of objects is proposed. Robots are used to move the sensors around the scanning object in order to scan the object in various positions and orientations. A marker frame is used to accurately align the multiple scan data measured in various positions and orientations. A prototype system is implemented by using Solutionx's Rexcan scanner and Samsung's Faraman robot.

5. ACKNOLODGEMENT

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