DEVELOPMENT OF THREE-DIMENSIONAL MEASURING TECHNOLOGY AT HIGH SPEED AND AT HIGH RESOLUTION

Satoshi Suzuki , Ken'ichi Kamijo
Pulstec Industrial Co., Ltd.
Imas Ohski Bldg, 5F 1-20-3 Ohsaki, Shinagawa-ku, Tokyo, 141-0032
E-mail: LEB02310@niftyserve. or. jp FAX: +81-3-5434-5008
JAPAN

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ABSTRACT

We will present the development of our three-dimensional technology by the non-contact and laser scanning method for integrated application systems. And we will also present the function about the new type of scanner which can easily acquire a flexible range depth data of objects by laser scanning method and output video signal to image processing systems

1. INTRODUCTION

There are various kinds of technologies which manufacturers are developing or have already developed for the non-contact three-dimensional data acquisition systems. These technologies consist of following elements.

1: Video CCD camera and slit-laser lighting
2: Video CCD camera and cord patterned lighting
3: Video CCD camera and moiré patterned lighting
4: PSD (Position Sensing Device) and laser probe lighting which is scanned by the galvanic mirrors.
5: Photodiode and laser probe lighting which is scanned by the galvanic mirrors. (Phase shift method)
6: Line-CCD and laser probe lighting which is scanned by the galvanic mirrors.

We conducted several experiments on technologies to find the best method for our Three-dimensional Scanner.

When we tested the elements(NO 1,2,3) we acquired a high video sampling rate but a long data processing time was necessary. When we tested the elements(NO 4) , we found that the sensitivity of the PSD was lower than the Line-CCD and the sampling time of the PSD was longer than the Line-CCD. And we also found that one of the highest levels of technologies was consistent with element (NO 5). However, it would cost too much for us to develop this technology and would not expand our sales of these expensive products therefore, we decided to develop the technology that consists of the Line-

Table 1: Comparative List of the elements (NO 1.1, 1.2, 1.3, 1.4, 1.5, 1.6)

Items	1	2	3	4	5	6
Sampling time	33 m sec	33 m sec	33 m sec	5～10 sec	-	2～10 sec
Processing time	slow	slow	slow	rapid	-	rapid
Sensitivity of object's gray level	unstable	unstable	unstable	unstable	-	stable
Sensitivity under direct sunlight (15000 LUX)	×	×	×	low	-	high

CCD, the Laser Probe, and the Galvanic Mirror. The Laser Probe scans object's surface at a high speed instead of a contact probe. The distance is processed by triangulation method with the sensing point of the Line-CCD which senses the reflection light from the object. X-Y-Z coordinates would be processed with the Laser Probe direction angle and the distance in the view area.

2 OUR TECHNOLOGY

2.1 Features

The three-dimensional scanning system consists of four parts which are the scanning head, the control unit, the personal computer, and the installed software.

The Laser Probe method enables a wide sensing range from dark to light gray level by APC(Automatic laser Power Control function) which can keep the optimum laser power despite various angles and gray levels of the object's surface. Every surface of the object is sensed except mirror and glass surfaces.

When the Three-dimensional Scanner is operating, the laser power is controlled within the range which satisfies the Class 3A safety standard.
During operation, the direction of the visible laser light is easily confirmed.
It is equipped with the high power laser and the wave band pass filter which enables low gain sensing with no negative effect of diffused reflection noise.
It can stably operate under direct sunlight of 15,000 LUX or less.

We supply five types of three-dimensional scanning heads depending on the working distance from 0.16 meters to 3 meters, the scanning rate from 1.8 seconds to 15 seconds, and the resolution from ± 30 micron meters to ± 10 millimeters in order to satisfy various kinds of requirements.

The three-dimensional scanner can operate in two scanning modes(2D mode and 3D mode). The 2D mode is used for sensing a moving object at constant speeds on such devices as a moving conveyor belt or a spin stand table. The single line of the scanning laser light stays on the same line and most of the object is sensed. The 3D mode is used for sensing a stable object. The single line of the scanning laser light scans a part of the object in 3D mode. More than three scanner heads are necessary for sensing the entire view of the object simultaneously.

The whole three-dimensional view of the object can be formed not only in sensing constantly moving objects with the 2D mode, but also in sensing stable objects from different directions with the 3D mode. The software consists of three parts: Base Function, Option 1, and Option 2 (See Table 2).

2.2 Our Current Products

We are developing a new type of three-dimensional scanner which outputs the video signal with the flexible depth range data. The new type consists of the laser scanning head and the control unit. A personal computer is not necessary for the new products. The control unit is equipped with the electronic CPU board and outputs the three-dimensional sensing data with composite video signal (NTSC or PAL) .

The number of dots in the plane sampling rate range from 12,800 to 128,000. Each dot has X-Y coordinates and eight-bit gray levels. The flexible depth range data is indicated with the eight-bit gray levels instead of the Z coordinates.

Image processing system can be upgraded to a three-dimensional image processing system by connecting our brand new three-dimensional scanner instead of a video CCD camera.

We are also developing another new type of three-dimensional scanner which has more than ten meters working distance for remote sensing.

2.3 Our International Distribution

Currently, we cannot supply any three-dimensional scanners internationally because we cannot provide sufficient local technical support, however, we plan to start international distribution of a new type of 3D scanner which outputs NTSC or PAL video signals in

the near future. A personal computer will not be necessary for this type. It will consist of the scanning head and the control unit. We will provide operation manuals, installation training manuals and technical support information.

3 CONCLUSION

We supply our products for the following applications:

3.1 Robot Arm Acquisition System

The scanning head is designed compact enough to be equipped with a robot arm. The robot arm is operated by the robot control unit which is connected to the three-dimensional scanner. The signals of the three-dimensional coordinates of the objects' center are output from the three-dimensional scanner to the robot control unit. This is highly effective with objects that are not uniform in sequence.

3.2 Welding Line Tracing System

This type of machine is operated by its control unit which is connected with our three-dimensional scanner. The welding head automatically traces according to the welding line.

3.3 Reverse Engineering System

The whole three-dimensional view of the automobile clay-model is formed by the 3D mode sensing from different directions, and the CAD format feedback data is sent to CAD systems.

3.4 Figure Measuring System

The three-dimensional scanner scans the model's figure and apparel then the system analyzes and processes the information to integrate design simulation systems.

3.5 Three-dimensional Inspection System

The three-dimensional view of complete products is checked in a production line by a three-dimensional inspection system which is equipped with our Three-dimensional Scanner.

3.6 Structural Data Acquisition System

Our new type of scanner will offer a function that allows you to sense surfaces and the arrangement of buildings under direct sunlight from a long working distance view point.

OUTLINE OF PULSTEC

Pulstec was established in 1968.
The company went public in 1996.
ISO 9001 was certified by JMC in 1997.
Headquarters: Hamamatsu-shi, Shizuoka-ken, Japan.
President: S. Tagaya
Total annual turnover: ¥12,000M (US$100M) approx.
Employees: 460 approx.
Operations: Developing, designing, and manufacturing three-dimensional scanners and optical disc testers, optical pickup head testers, and electric circuit boards testers.

Sales person in charge: Ken'ichi Kamijo
Sales Promotion Manager,
TokyoOffice, Pulstec
Industral Co., Ltd. Imas
Ohsaki Bldg, 5F 1-20-3
Ohsaki, Shinagawa-ku,
Tokyo. 141-0032 Japan
Fax: +81-3-5434-5008
E-mail:
LEB02310@niftyserve.or.jp

Table 2: SPECIFICATIONS LIST

2.1 Scanning Head

Measuring Mode	View Angle	Plane Sampling Rate	Scanning Time
A	18°×14.4°	128×100	1.8 sec.
B	18°×14.4°	256×200	6.5 sec.
C	30°×28°	220×140	4.0 sec.
D	30°×28°	460×280	15.0 sec.

Required Condition	Illuminance	Less than 15000 LUX
	Temperature	10℃～35℃
	Humidity	20%～95% (Non-condensing)
Laser	Semiconductor Laser λ : 680nm Maximum Laser Power: 12mW Class 3A APC (Automatic laser Power Control function) : Laser power is automatically changed according to the gray levels of objects' surface	
Dimensions	W : 71mm H : 132mm L : 138mm	
Weight	15000g	

Items	TDS-0216	TDS-0320	TDS-0503	TDS-1500	TDS-3100
Working distance	160～200mm	200～300mm	300～500mm	500～1000mm	1000～3000mm
Laser beam diameter	0.3mm φ	0.5mm φ	0.7mm φ	1.2mm φ	2.0mm φ
View area	107×100mm	160×149mm	270×252	530×495	1600×1493mm
X-Y Resolution	±0.15mm	±0.25mm	±0.35mm	±0.6mm	±1.2mm
Z Resolution	±0.03mm	±0.04mm	±0.07mm	±0.3mm	±1.25mm

2.2 Control Unit

Items	Type 1	Type 2
Output Signal	Parallel I/O (20bit) X-Y-Z coordinates data	Video Composite: NTSC/PAL Z coordinate data is displayed with 8 bit gray levels of each dot
Plane Sampling Rate	128×100～460×280	256×256～512×512
Connection to Peripheral equipment	Designated personal computer by the electric interface board	Image processing equipment by BNC cable
Required condition	AC 100V 0.5A	T. B. D.
Dimensions	W : 100mm H : 210mm L : 320mm	T. B. D.
Weight	5.2kg	T. B. D.

NOTE: Items marked "*" satisfy following functions. We supply this software domestically. OS: Windows NT 4.0 (Windows NT is the registered mark of Microsoft Corporation). 32 MB of RAM is required. 50MB of hard disk space is required. Any specifications may be changed without advanced notice.

2.3 Software

Items	Functions	Basic	Option 1	Option 2
Operation	Sensing area setting mode	*	*	*
	Indication setting mode	*	*	*
	Laser condition setting mode	*	*	*
	2D / 3D setting mode	*	*	*
	Scanning data acquisition mode	*	*	*
	Scanning method setting mode	*	*	*
Measuring	The angle between the line and plane	*	*	*
	The angle between two different planes	*	*	*
	The angle between two different lines	*	*	*
	The distance between two different points	*	*	*
	The distance between the point and the plane	*	*	*
	X-Y-Z coordinates	*	*	*
	Cross section: circumference/area/distance between two different cross sections		*	*
	Area of the object's surface		*	*
	Tracing distance		*	*
Composition	Wide range three-dimensional view composed of different views which sense the object from different directions		*	*
Data File	ASCII / BMP / DXF	*	*	*
View Simulation	Move/Zoom/Two-dimensional rotation/Three -dimensional rotation	*	*	*
Shading			*	*
Graphics	Polygon/Surface			*