BL (Body Line) Scanner

The development of a new 3D measurement and Reconstruction system

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ABSTRACT

BL scanner is a 3D whole body measuring system for underwear and outerwear. In the apparel industry, research and development of clothing to provide comfort size to fit and maintain beautiful body shape are pursued quite actively. Furthermore, major factories aim at Mass Customize by using CAD and CAM. To realize these purposes, it is necessary to develop a measurement system that can detect three dimensional body shape easily, quickly with low cost price. Therefore, we developed the BL scanner that is constructed by using an Optical Triangular Surveying. In this system, the light source has been developed newly, a compact LED array which provides 32 luminous points. Detector has also been contrived newly, a called Segment-PSD (Position Sensitive Detector) to improve the detect precision. One scanner head employs a LED array and two Segment-PSDs. The 8 sets of scanner head are arranged around a measured human body and moved from the top of the head till the bottom of the feet of a human body. The system's performance are set: measuring time is about 10 seconds, accuracy is ±1 mm. The measuring data is transferred to Windows PC to be displayed in a silhouette, wireframe and surface mode. At present, BL scanner is practically used for underwear, and we are trying to convert the measuring data to DXF file that can be utilized by apparel CAD. In future we hope to apply the system in medical facilities, sports science, amusement etc.

1. BACKGROUND OF THE DEVELOPMENT

1.1 Product of a clothing

Most of apparel products aim from mass production to mass customization. The advantages of this inclination can provide so called "size to fit" to customer and a few stock, few return clothing to cloth makers and shops.

While a price for traditional tailor-making was expensive, one of mass customization is not so expensive because of benefit of apparel CAD and CAM system. It is a last problem to practice automatic measurement for pattern making design.

Although some whole body measurement systems have already made for study, there are few systems could be used into the practice for commercial base. Therefore, we had a plan to develop a three dimensional automatic measuring system.

1.2 Concept of the development

As a progress to develop the BL scanner, we have some concepts as following.

(1) low product cost to be profitable for commercial base
(2) safety for a measured human body
    (include mechanical, electrical and radiation factor)
(3) comfortable for a measured person
    (include vibration, sound and brightness factor)

(4) whole body measuring time is less than 10 seconds
(5) small size system for taking up less space
(6) raw measuring data size is less than 300 K byte
(7) maintenance-free or simple maintenance

The item (1) is important for the commercial application. (2) needs to keep each safety regulations. In generally, ordinary people have some inferiority complex to their body. Therefore, they would not like to measure their body size. Furthermore, if the measured person feels anxious during measuring time in the system, the measuring system would no longer become popular. Then we recognize (3) is very important. We can not keep the same posture for a long time. If the measured body moves during the measuring time, we can not obtain the correct data. Therefore, the system requires short measuring time. Then we tried to select the measuring method that satisfy the qualification (4). Most of apparel shops are in downtown. The land price is very expensive. Therefore, the measurement system requires item (5). If the measuring data size is very large, it needs very long time for the data processing by a computer. Then small raw data size like (6) is preferred. If the measurement system would become popular, item (7) is very important. We started the development of 3D measuring system according to above concept.

2. PRINCIPLE MEASURING METHOD

2.1 Optical system for distance detection

Our B/L scanner adopts triangle measuring method. The principle is shown in Fig.1. We use IR-LED Infrared Light Emission Diode) as a light source because of eye safety. The luminous flux from the IR-LED is focused on the surface of the measured object by the projection lens. The irradiated luminous flux are reflected diffusely on the surface. Some of the diffused reflecting luminous flux pass through the receiving lens, and focus on the photodetecting area of the Segment-PSD (Position Sensitive Devices). With respect to the positional relationships in the figure, the following assumptions are made: the base line is B, the distance detection range is from L_N to L_F, the distance from the receiving lens to the photodetecting area of the Segment-PSD is f, the distance from the optical system to the measured object is L_X, the distance from the optical

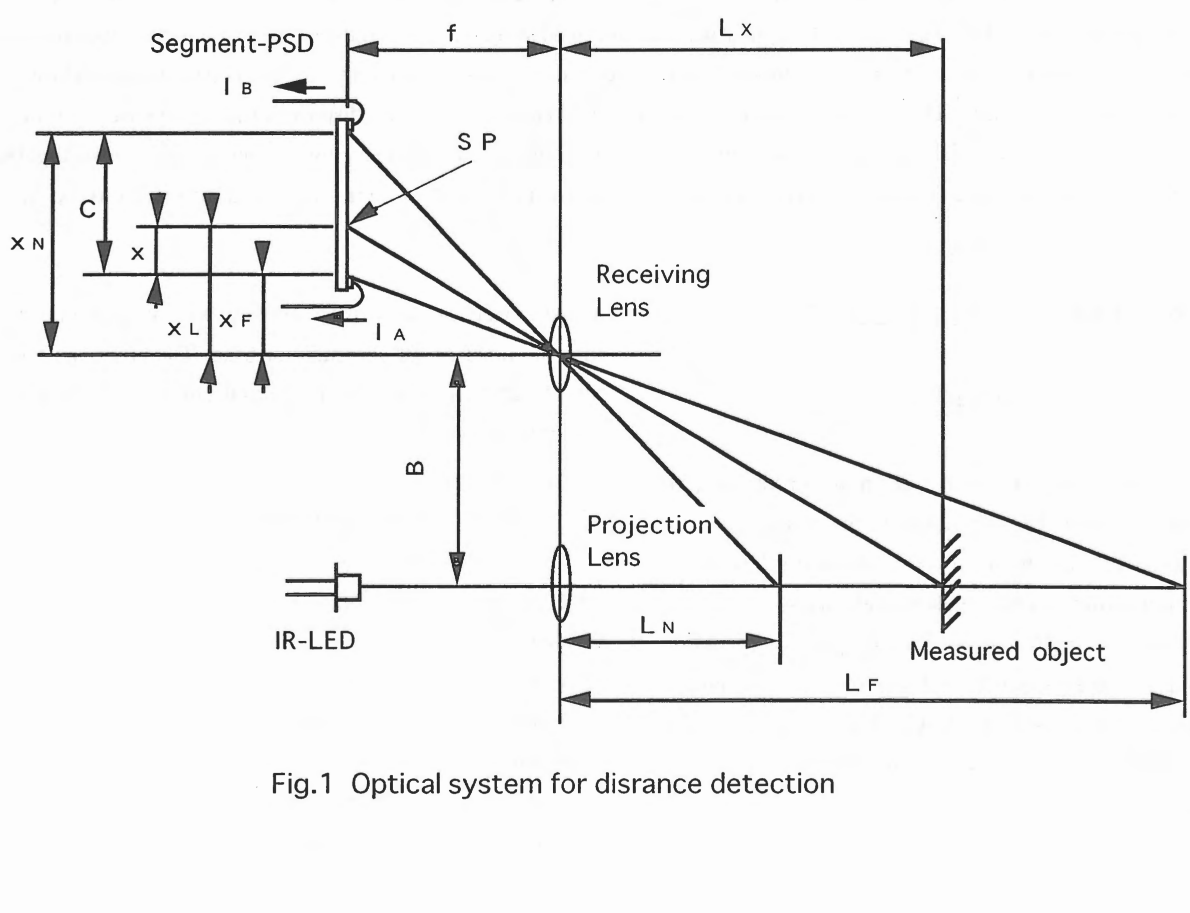

Fig.1 Optical system for disrance detection

axis of the received lens to one end of the photodetecting area of the Segment-PSD is x_F, the distance to the opposite end is x_N, and the position where the reflected diffusely luminous flux from measured object is focused on the photodetecting area of the Segment-PSD by received lens is called SP. Furthermore, it is assumed that the distance from the position SP to one end of photodetecting area of the Segment-PSD is x, the distance from the optical axis of the received lens to the position SP is x_L, and the length of the photodetecting area of the Segment-PSD (distance between a pair of electrodes) is C. Thus, the following relations hold.

$$x_F = \frac{f \cdot B}{L_F} \quad \cdots\cdots (1)$$

$$x_N = C + x_F = \frac{f \cdot B}{L_N} \quad \cdots\cdots (2)$$

Hence, Eq. (3) is derived from (1) and (2).

$$C = f \cdot B \cdot \left(\frac{1}{L_N} - \frac{1}{L_F} \right) \quad \cdots\cdots (3)$$

Furthermore, the following relation is also obtained from Fig. 1.

$$x = x_L - x_F = f \cdot B \cdot \left(\frac{1}{L_x} - \frac{1}{L_F} \right) \quad \ldots (4)$$

With respect to the Eq.(4), we assume that the distance Lx to the measured body object, is variable. Therefore, the distance x from one end of photodetecting area on the Segment-PSD to the light condensed position SP, is the inverse of Lx. It is obtained from Eq. (5).

$$x = -\frac{C}{2} \cdot \left(\frac{I_A - I_B}{I_A + I_B} \right) \quad \cdots\cdots (5)$$

With respect to the Eq.(5), we assume that I_A, I_B are out put photocurrent of the PSD, respectively.

2.2 Segment-PSD

A Segment-PSD has two-part photodetecting areas. If the manufacturing specification for these two-part areas are divided uniformly, the distance resolution at the far side remarkably deteriorates because it is inversely proportional to the distance Lx as indicated by Eq.(4) and (5).

This problem is the characteristic of the optical triangle measuring method, then it must be improved in order to increase the measurement accuracy. Figure 2 presents a scheme of the division pattern of the two-photodetecting

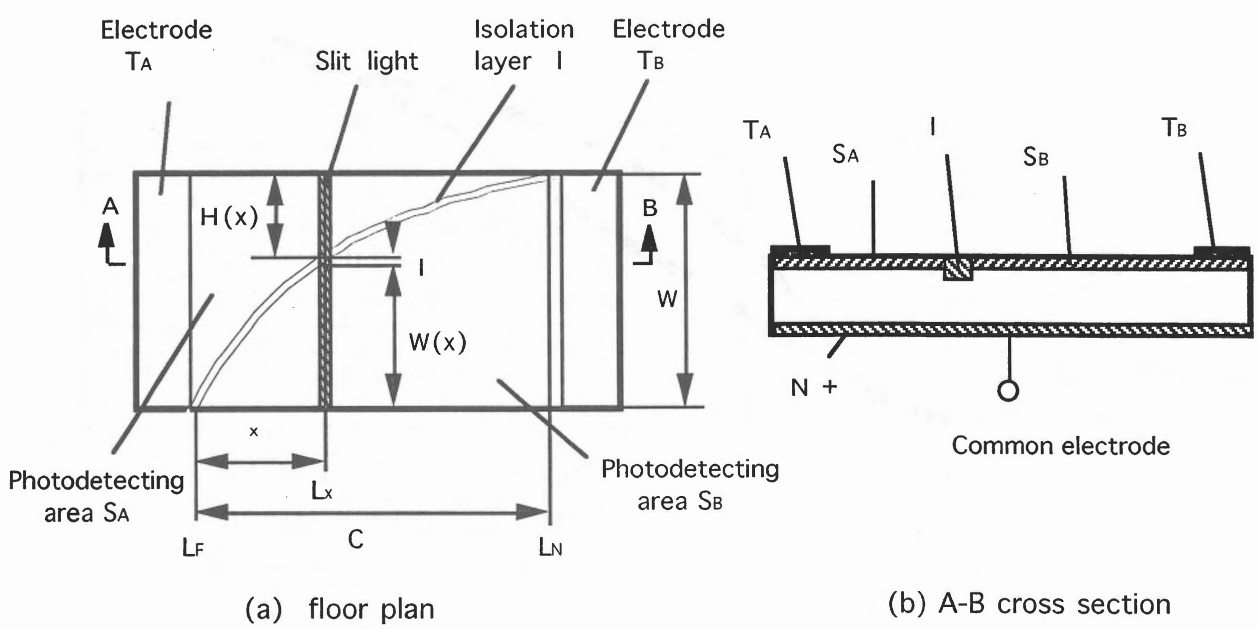

Fig.2. Structure of Segment-PSD

areas of Segment-PSD which was designed in order to alleviate the above problem. Photodetecting areas S_A, S_B built on a silicon wafer are separated by the isolation layer I, and mounted with electrodes, T_A and T_B, respectively, to draw photocurrent.

The following is the positional correspondence between Figs.1 and 2. The Segment-PSD is arranged so that electrode T_A is set up the side of the light source (IR-LED) in Fig.1. The slit light of the reflected luminous flux from the measured body object located a distance L_F is converged by receiving lens on electrode T_A, as illustrated on the left in Fig.2. The slit light of the reflected luminous flux from distance L_N is converged on T_B as illustrated on the right in Fig.2. Then slit light from distance Lx irradiates the hatched sloping part in Fig.2. Here, arrangement is made so that the following relationship holds between H(x) and W(x), which represent the length of the slit light irradiating a pair of photodetecting areas S_A and S_B, respectively, assuming that the distance from the left edge of the photodetecting area to the center of the slit light is x.

$$H(x) + W(x) + I = W \quad \text{................} (6)$$

$$W(x) = \frac{ax}{x + b} \quad \text{............................} (7)$$

where W and I represent the total length of the photodetecting areas and the width of the isolation layer, respectively. Also ,a and b represents the constants given by the following equations:

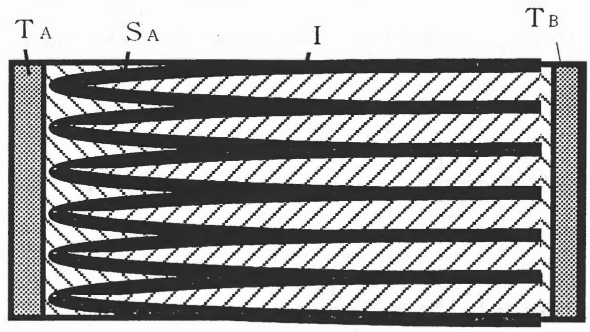

Fig. 3 Pattern structure of segment PSD

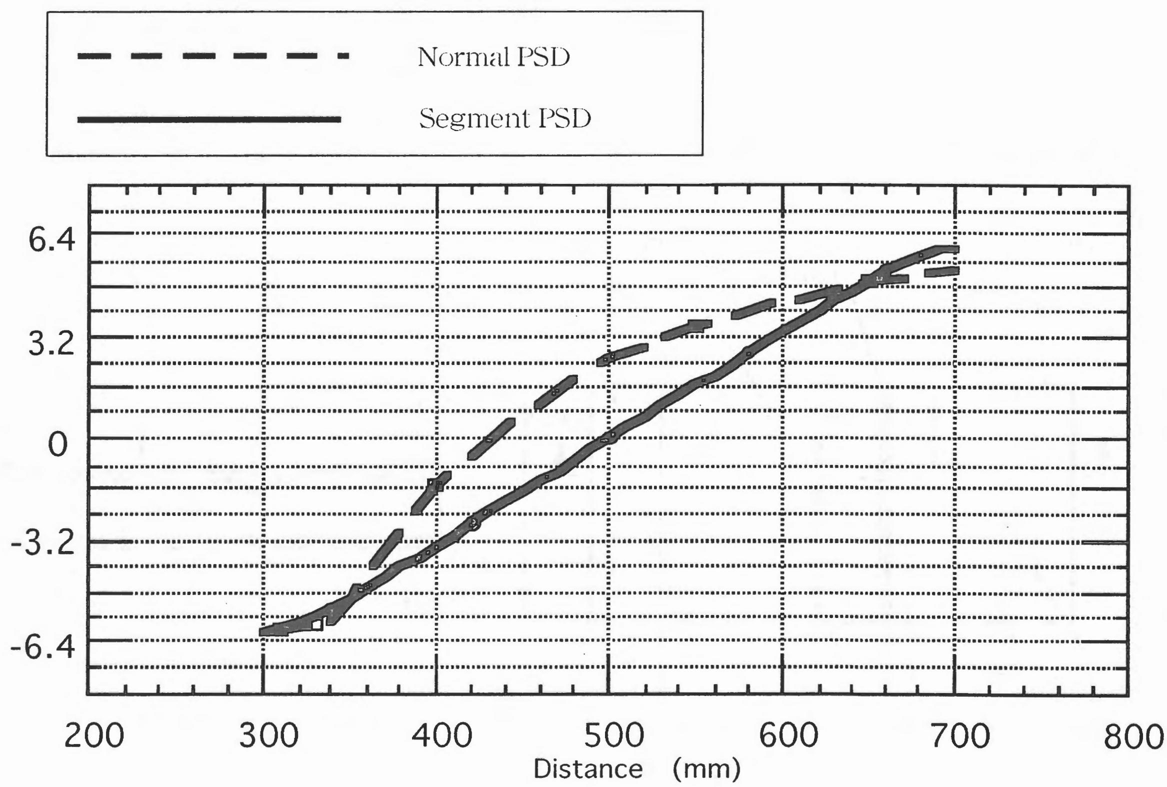

Fig. 4 Output characteristics

$$a = \frac{L_F (W-l)}{L_F - L_N} \quad \text{.............................} (8)$$

$$b = \frac{f \cdot B}{L_F} \quad \text{...................................} (9)$$

When I_A and I_B represent the photocurrent drawn from electrodes T_A and T_B mounted on photodetecting areas S_A and S_B, respectively the following relationship hold:

$$I_0 = I_A + I_B \quad \text{..............................} (10)$$

$$I_A = \frac{H(x)}{H(x) + W(x)} \cdot I_0 \quad \text{........} (11)$$

$$I_B = \frac{W(x)}{H(x) + W(x)} \cdot I_0 \quad \text{........} (12)$$

The position of the slit light irradiation is obtained by the following equation, irrespective of changes in the strength of the light.

$$\frac{I_A - I_B}{I_A + I_B} = \frac{H(x) - W(x)}{H(x) + W(x)} \cdot I_0 \quad \text{...} (13)$$

If the pattern of the isolation layer is designed such that it satisfies Eqs. (6) through (7), the signal operation value obtained by Eq. (13) will be linear and proportional to the distance within the distance measurement range L_N through L_F, which makes it possible to obtain a uniform sensitivity. It should be noted that the photodetecting areas are not always irradiated by ideal narrow slit light when this Segment-PSD is applied to distance measurement. For example, the photodetecting areas may be irradiated by a round spot light or slit light including some width. Furthermore, if the longitudinal irradiation density of the slit light is not uniform, it is impossible to obtain the signal operation value that is directly proportional to the distance. In order to solve this problem, the photodetecting area pattern of the real Segment-PSD was manufactured in the pattern which consists of multiple wedge patterns arranged in parallel as illustrated in Fig.3.

2.3 Characteristic of the Segment-PSD

Figure 4 illustrates the differences of the output characteristics of normal PSD and Segment-PSD. The solid line represents the data obtained by Segment PSD, and the dotted line represents the data obtained by normal PSD. The data obtained by Segment-PSD represents approximately a straight line throughout the measurement range of 350 to 650mm. In contrast, the graph of the data obtained by normal PSD is steep on the short distance side, indicating that the distance detecting sensitivity is high; however, its slope becomes very gentle on the long distance side, indicating that both distance detecting sensitivity and distance resolution decrease with the increase of distance.

3. SCANNER HEAD

It is generally considered that the measurement accuracy of the optical triangle method has high resolution, but it needs long measuring time because it is based on the principle of one point measurement. Until now, we were having a perception including presuppose as following, i.e., if we applied the optical triangle measuring method to 3D measurement, it needs to make a 2D mechanical scanner. If it is possible to realize an optical triangle measuring method that replaces 1-dimensional mechanical scanning with electrical scanning, the measurement speed will be increased to the level equal to the light-section measuring method by using a TV camera, or even higher because the signal operation is simpler.

3.1 Optical system of Scanner Head

Figure 5 illustrates the optical system of the scanner head used for the BL scanner. By using near infrared LED array as alight source and lighting each IR-LED by means of pulse lighting by time division, apparently the same effect as the electric scanning on the surface of measured object by a condensed scanning beam is obtained. Incidentally, the light source used for this scanner head has 32 IR-LED elements, and the lighting pulse width is set to 30 μ sec. Because the interval between turning off an element and turning on the next element is also set to 30 μ sec, one scanning cycle took 1.92 msec.

The luminous flux emitted by each element of the IR-LED s condensed by a projection lens and irradiated on the surface of the measured body object. The reflected luminous flux that comes back from the measured body object is condensed on the segment photodetecting area of the Segment-PSDs positioned axisymmetrically against the optical axis of the projection lens, by a pair of receiving lenses installed also axisymmetrically against the optical axis of the projection lens.
A pair of receiving lenses as well as a pair of two Segment-PSDs are used to compensate for the errors that are produced when an incomplete irradiation pattern is formed at the measured point due to the eclipse of the irradiation beam. Compensation is achieved by an analog operation of equation (13) using I_A and I_B, where I_A means the photoelectric current drawn from the electrode T_A of Segment-PSD on the projection lens side, and I_B means the photoelectric current drawn from electrode T_B on the opposite side of the projection lens.
The above analog and digital operation for obtaining the distance to each irradiated point is completed within 30 μ sec, i.e., the period of lighting of the IR-LED. Hence, scanning and measuring time are accomplished simultaneously.
Next, Photo.1 shows a exterior of Scanner head. It has three lenses which are made by an aspherical glass casting press method. The both side lenses are added a cylindrical lens because of making slit light.

4. BL SCANNER

4.1 Arrangement of Scanner Head

In order to take a three-dimensional measurement of the whole body of a subject, eight scanner heads are arranged in the BL scanner so that they encircle the whole body.. Figure 6 illustrates the arrangement of eight scanner heads for the top-view. Hence, the number of horizontal measurement points are $8 \times 32 = 256$.

4.2 Arrangement cf Scanner Head

Figure 6 illustrates the structure of BL scanner.
A measured subject is standing on the stage covering with transparent acrylic resin windows and metal boards.
Scanner heads are mounted on a head setting arm. The head setting arm is connected with a wire, and another end of the wire is connected with a balanced weight because of a small driving motor make possible to use. The scanner head is also connected a carrier to be able to move on the guide rail for using timing belt and motor. The encoder is used for timing control of measuring action. If we turn on the SET switch on the operating panel, the head setting Arm move up to the top. Next, if we turn on the measuring START switch, the head setting Arm so down and scanning the measured body.

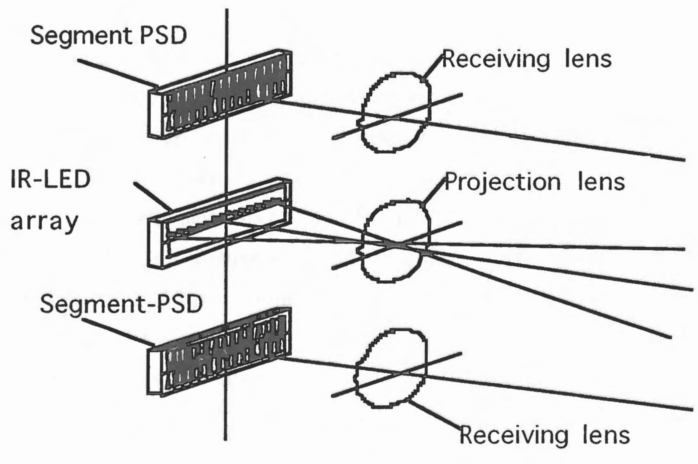

Fig.5 Optical system for scanner head

Photo.1 Exterior of Scanner head

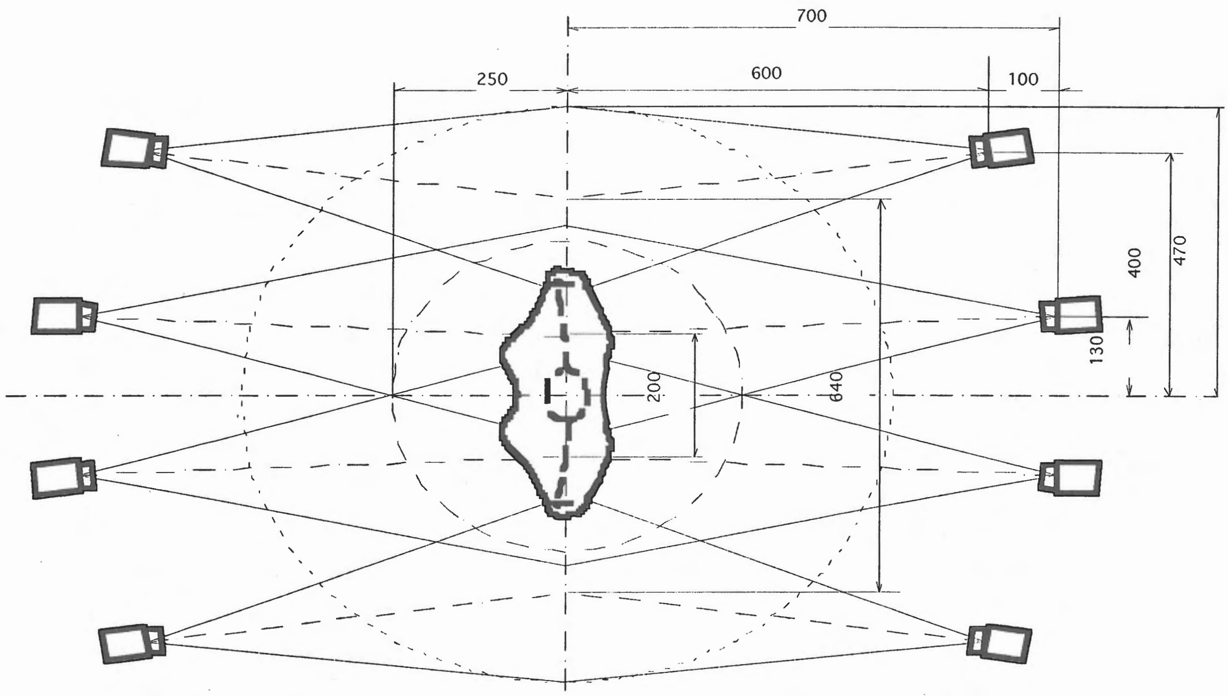

Fig. 6 The arrangement of the Scanner Head

Photograph 2. illustrates the external appearance of the BL scanner. The measured woman is standing approximately at the center on the stage. She grasps a poles lightly to easily keep unmoved while the system is scanning. In actual situation, the entrance is closed by a curtain during.

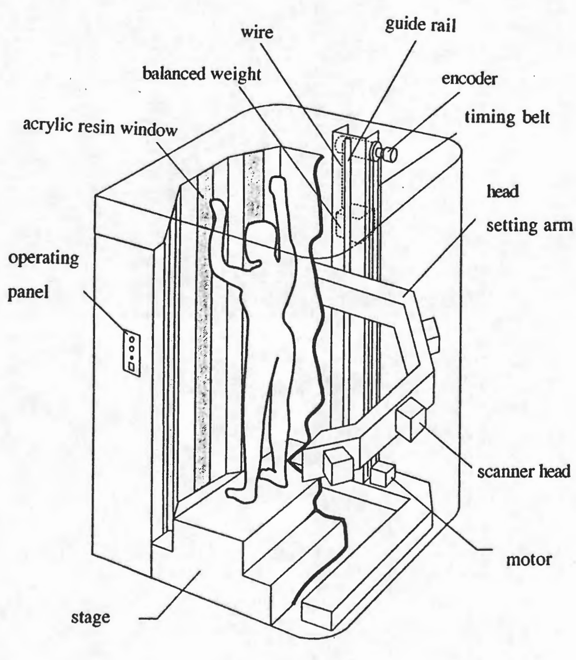

Fig.7 Structure of BL scanner

Photo.2 Exterior of BL scanner

the measuring time. Pressing the measurement start switch on the operational panel installed to the left of the entrance initiates the measurement operation, and the measurement is completed within 10 seconds.

4.3 Measured DATA

8 scanner heads are set on the arm with the shape of a horseshoe. This arm is made vertically movable over 195 cm range. In the case of outerwear, the range of vertical measurement was set to 185 cm, and measurement points were taken at the interval of 5 mm along this range. One point measurement data consists of 2 bytes for a distance data and 1 byte for a reflective light intensity. As a result, the measurement data for a whole body consist of 285 Kbytes (distance data : 190 Kbytes, intensity data :95 Kbytes).

The entire measurement is designed to be completed within approximately 10 seconds. The scanner heads have the capacity of completing entire measurement within 5.7 seconds. The rest of the time is spent for moving the 8 heads vertically by 185 cm because the load caused by the acceleration and retardation of the heads is heavy. Slow vertical movement speed enables the reduction of inertial force and the use of a small driving motor.

The measured body subjects is required to take a static state while the measurement are taken. However, experiments have proved that the majority of the measured subjects felt almost no discomfort in taking static state within 10 seconds.

4.4 Example of 3D Display

Both the distance data and reflected intensity data are transmitted to a Personal Computer (PC) via a GP-IB interface. The distance data are converted to the data of the cylindrical coordinate with the axis at the imaginary center where the measured body subject stands. The reflected intensity data are used as a mean of determination to nullify distance data when the irradiation beam does not hit the

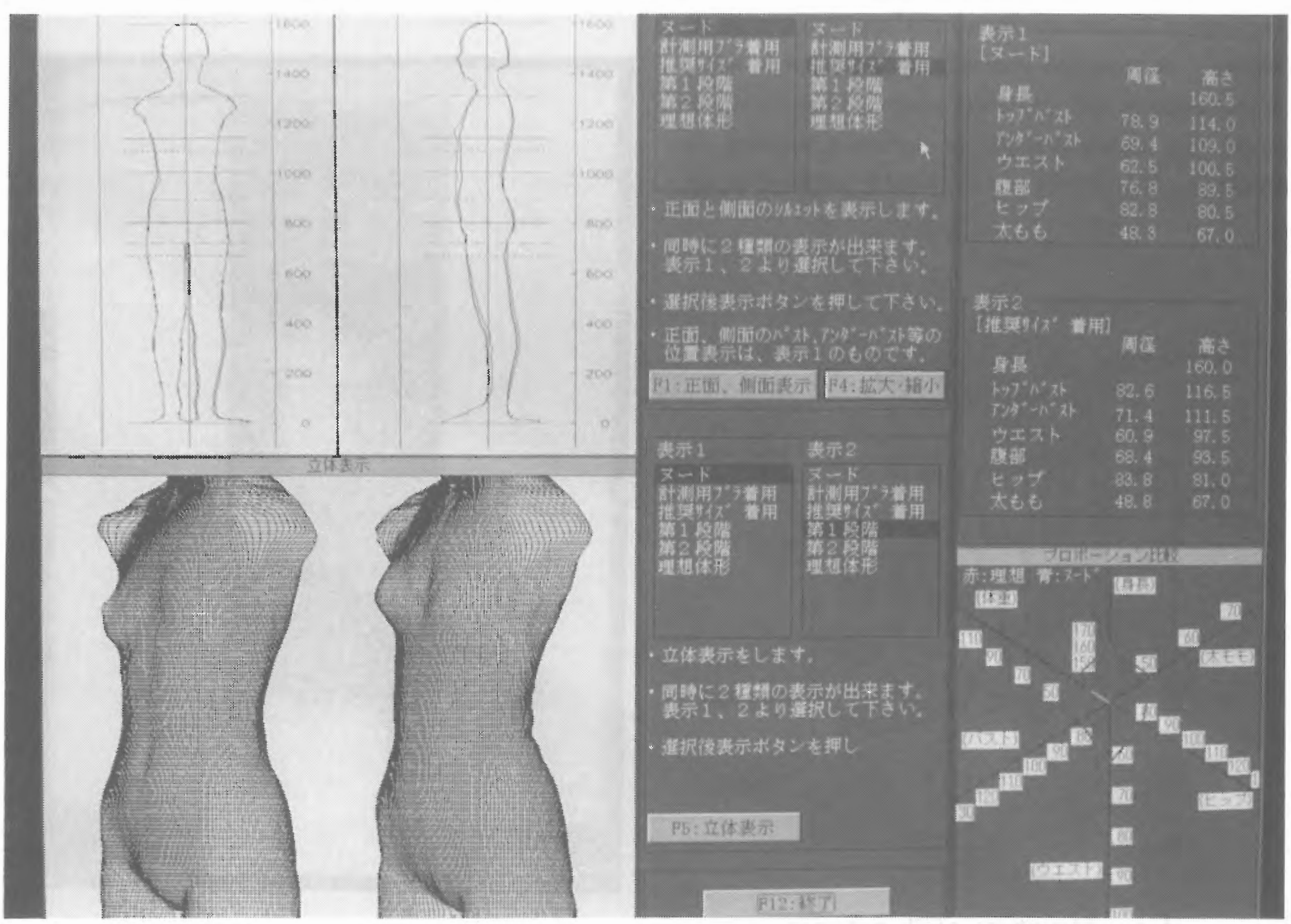

Photo.3 Example of display of measurement data(Courtesy of Hokuriku STR)

measured body subject and bypasses it. They are also used for diagnosis when abnormal data arised. Photograph 3 illustrates a set of sample three dimensional data displayed by PC. The figures on the lower left display measurement data by means of wire frame when nude body and body worn with an under wear are measured. We can ascertain the difference from the compared bust-ups. The figures on the upper left parts display the silhouettes of the measured body subject viewed from the front and the side. The two silhouette lines are shown for the nude body and the worn body. We can also select many other expressed parts by the operating in the center menu column. The calculated numerical data are shown in the column on the upper right. The figure of proportion parameters is shown on the lower right.

5. CONCLUSION

A body contour scanner for taking three dimensional measurements of a subject was developed by fabricating the Segment PSD. As a result, it became possible to realize superior performance in terms of signal-to-noise ratios, response characteristics, and measurement accuracy which could not be realized by the conventional electric divided resistance position sensitive detector (Normal PSD). This result demonstrates that the Segment PSD is expected to be used as the photodetecting device for position detection by optical triangle measuring method in the future. Also, the scanner head that was developed by combining the Segment PSD with an IR-LED array enables high speed 1-dimensional scanning, making it possible to realize high speed and high accuracy three dimensional measurement. In the future, the realization of a higher resolution 3D shape measurement instrument will be pursued by the density rate of the IR-LED array. The pitch of the first step IR-LED array which we have used, was 0.8 mm. In the second step IR-LED array, the pitch would be 0.4 mm.

We hope that this BL scanner advance to make possible to use many other application. For example, it is needed to measure a volume or skin area of patients in a medical application. Also, it can monitor a growth process of a body for babes, children and students. It is important that a body shape is checked for a sport, a calisthenics and health care.

In near future, all most people will become to order their best fit garments which are produced by using their own electric mannequin. This electric mannequin means a body-shape data card that is memorized a measurement data of customer.

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