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3D形状と輝度（色）の同時計測が可能なスキャナとその顔画像入力への応用

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概要　物体の3D形状と表面カラーの同時計測が可能なスキャナとその顔画像の計測への応用について述べる。レーザ光源およびCCDセンサと（3D距離計測用）、カラーCCDカメラ（カラー計測用）を搭載したユニットが中心のテーブル上に置かれた物体の周囲を回転し、3D距離データとカラーデータを同時に求める。レーザによる距離計測は512本の垂直方向走査線に沿って行なわれ、一走査線あたり256点分、総計512＊256点分の距離データが得られる。計測解像度は直径350mm、高さ350mmの円柱を計測した場合で0．7mm以内である。カラーデータは512x256画素、24bit／画素（r，g，b各8bit）のカラー画像として求められる。一回の実計測時間は15秒である。本装置を顔画像の計測に応用し、良好な結果を得た。

A Synchronized Cylindrical Range and Color Data Scanner and Its Application to 3D Face Data Acquisition

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Abstract

This paper presents a method of 3D human face measurement by using a newly developed device that acquires 3D range data and surface color data at the same time. The cylindrical range data is measured by a laser light source and a CCD sensor with the resolution of 512 vertical scan lines, 256 points per scan line. The color data is acquired as a cylindrical projection image having 512 by 256 pixels, 24 bits/pixel (8 bits for red, green, and blue, each). The scanner has been successfully applied to the measurement of human faces.

1 Introduction

The authors have been doing various researches on computer vision and graphics for the recognition and synthesis of human images, which are important in realizing better human interface and a model based CODEC in future [Mase'89][Aki'86][Aki'90][Wat'89] .

In this paper, the authors present a method of 3D human face measurement by using a newly developed device that acquires 3D range data and surface color data at the same time. The method described here is very useful for the acquisition and synthesis of 3D human faces and various 3D objects.

There have been already many publications and products on 3D range finders and scanners [Ino'90]. Almost all of them are designed for the detection of three dimensional distance or range data only. Though it has been regarded that ordinary color data can be acquired quite easily by usual color television camera or color scanners, the problem is not so easy.

Roughly speaking, in order to synthesize human faces by computer graphics, two kinds of data are needed: 3D shape (range) data and texture (color) data. Usually these two data are measured separately, using different kind of data acquisition systems as illustrated in Figure 1. Due to the time difference of two kinds of data, especially in case of movable objects like human faces, it is sometimes difficult to match these two data. Moreover, camera angles and lighting conditions may be very different from each other. Though some adjustment may be done to some extent, it is practically insufficient to acquire the consistent data of 3D objects having various shapes and colors. These problems arise not only for computer graphics generation of human faces. They may be significant for various applications such as synthesis and recognition of various objects based on 3D shape and color data.

The method presented in this paper is derived from the considerations stated above. Apparently it is desirable to acquire the range and color data at the same time, since it becomes possible to synthesize precise images of various objects from the synchronized 3D data as illustrated in Figure 2.

2 Scanner

The Echo scanner (4020/PS Rapid 3D Digitizer), manufactured by Cyberware Laboratories, USA, is a laser scanner to measure cylindrical range data of objects as illustrated in Figure 3. According to our specifications, the manufacturer installed a TV-camera based color data acquisition subsystem in the scanner while preserving its original functions, resulting in the first cylindrical scanner in the world to measure 3D range data and surface color data at the same time. The object to be measured is placed on a center table, and an arm having a laser light source, a CCD sensor and a CCD color camera rotates 360 degrees horizontally around it, acquiring cylindrical range and color data in synchronization.

The cylindrical range data is measured by a laser light source and a CCD sensor with the resolution of 512 vertical scan lines, 256 points per scan line. Measurement resolution is within 0.7 mm when measuring a cylinder having 350 mm height and 350 mm diameter. Actually the cylindrical range data is converted to 512 x 256 sets of x, y, and z coordinate values. Surface color data is measured by a CCD color camera. The color data is acquired as a cylindrical projection image having 512 by 256 pixels, 24 bits/pixel (8 bits for red, green, and blue, each). Since the cylindrical range and surface color are measured at the same time, all the data are acquired in a synchronized form.

3 Application to face data acquisition

Figures 4 (a), (b) and (c) illustrate an example of cylindrical range and color data acquisition using the machine. Figure 5 shows an example of 3D facial expression generation. Using a data subset cut from the data shown in Figures 4(a), (b) and (c). we generated a synthetic facial expression animation. In Figure 5, the left-most frames are generated from the original data. All other frames are generated by adding artificial modification in the 3D original data to animate a smiling expression.

4 Conclusion

We have been investigating an alternative method to acquire 3D face data by matching 2D front and side views with a generic 3D model [Aki'90]. Only a TV camera is needed as an input device and it takes a short time to grab two frames. But this method acquires 3D data by processing images to match 2D face data with a generic 3D face model. This method is based on a human head model, and is limited to face measurement only.

The method proposed in this paper is a general purpose 3D data acquisition method. This method has opened a way for us to acquire highly accurate data by directly measuring various 3D objects having surface textures. All the data are acquired in one horizontal rotation of the scanner arm. It takes the new scanner fifteen seconds to acquire the synchronized cylindrical range and color data.

Therefore, these two methods should be used in combination for human face measurement: the proposed method is suitable to acquire the generic 3D face model having texture data in high accuracy, and, front and side view based method [Aki'90] is suitable to the handy modification of the generic 3D face models.

The authors have been using the new scanner mainly for acquiring 3D data of human heads, hands, legs, and trunks. The proposed method is very useful to make a complete 3D image database of human bodies needed for realizing better human interface and model based CODEC. The method is also widely applicable to acquire synchronized 3D range and surface color data of various 3D objects. Therefore the proposed method will be very useful for preparing 3D image and/or graphics database of various objects needed in many kinds of applications.

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References:
[Aki'86] T.Akimoto,"Expressive facial animation by 3D jaw model and automatic shape modification", NICOGRAPH'86, pp207-213, 1986 (in Japanese).
[Aki'90] T.Akimoto, R.S. Wallace, Y.Suenaga, "Automatic synthesis of face model by using front and side view images," IEICE National Convention, No. D-340, March 1990 (in Japanese).
[Ino'90] S.Inokuchi,"State of the art of 3D sensing technologies", Gazo Lab. , Vol.1, No.4, pp44-47, April 1990 (in Japanese).
[Mase'89] K.Mase, Y.Watanabe and Y.Suenaga,"A real-time head motion detection system", SPIE Workshop on Sensing and Reconstruction of Three-Dimensional Objects and Scenes, Vol.1290, pp262-269, Santa Clara, CA, February 1989.
[Wat'89] Y.Watanabe and Y. Suenaga,"Drawing human hair using wisp model", CG International'89, pp691-700, 1989.

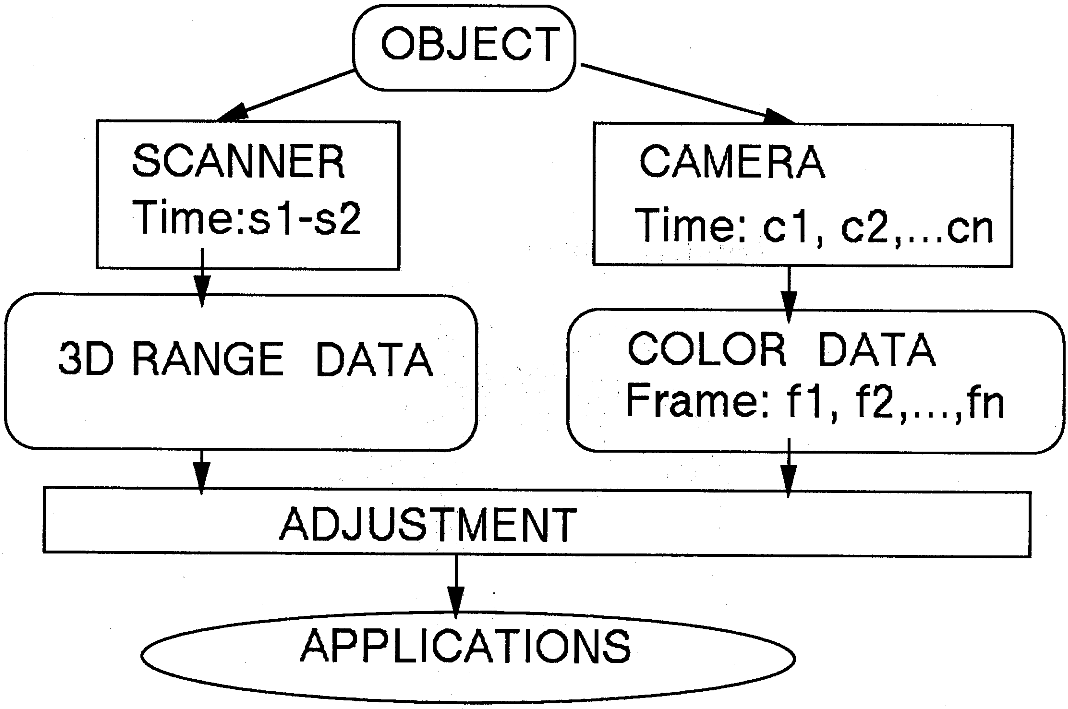

Fig.1 Usual acquisition of 3D range and color data

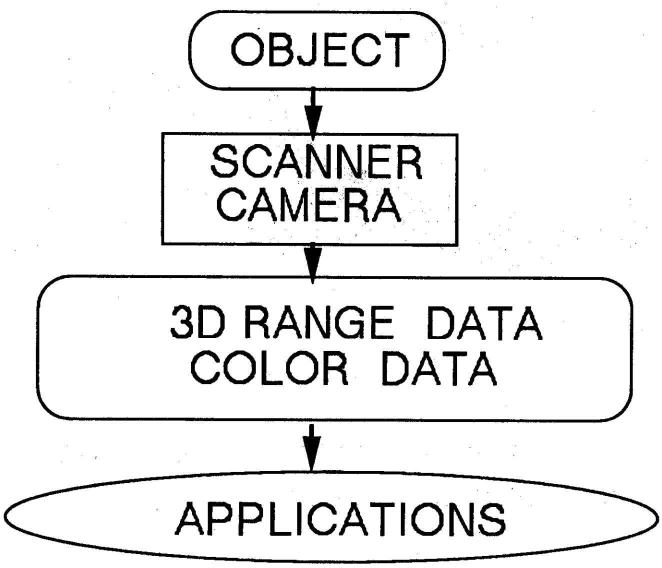

Fig.2 Synchronized acquisition of 3D range and color data by the scanner in this paper.

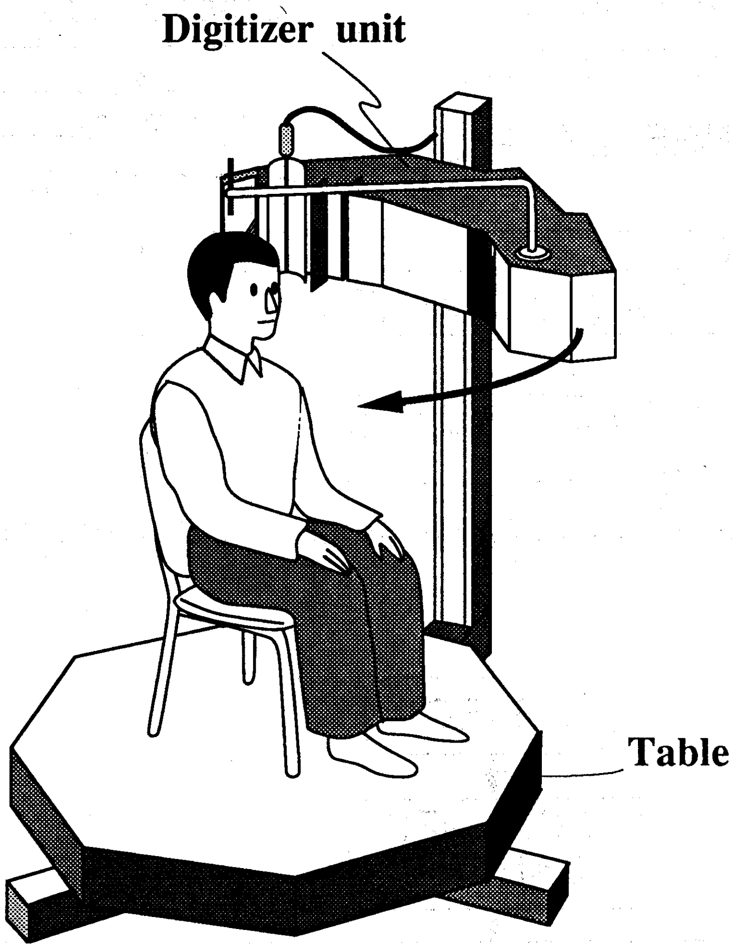

Fig.3 Face acquisition by synchoronized cylindrical range and color data scanner.

Fig.4(a) Front and side views made from range data only

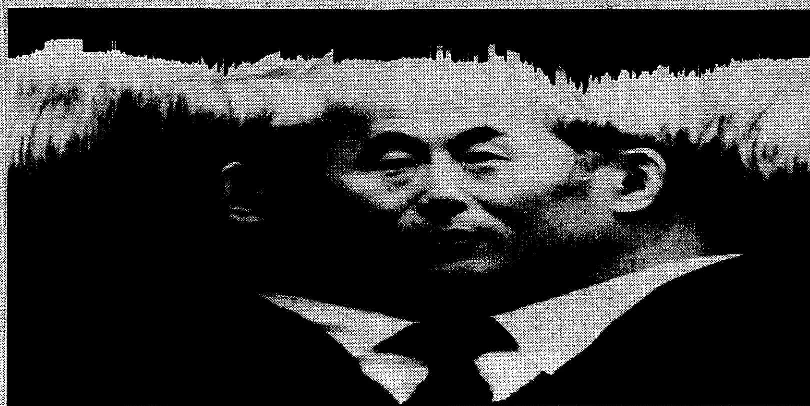

Fig.4(b) Color data (Inverse panorama, 512 x 256 pixels, 24bits)

Fig.4(c) Front and side views made from range data and color data.

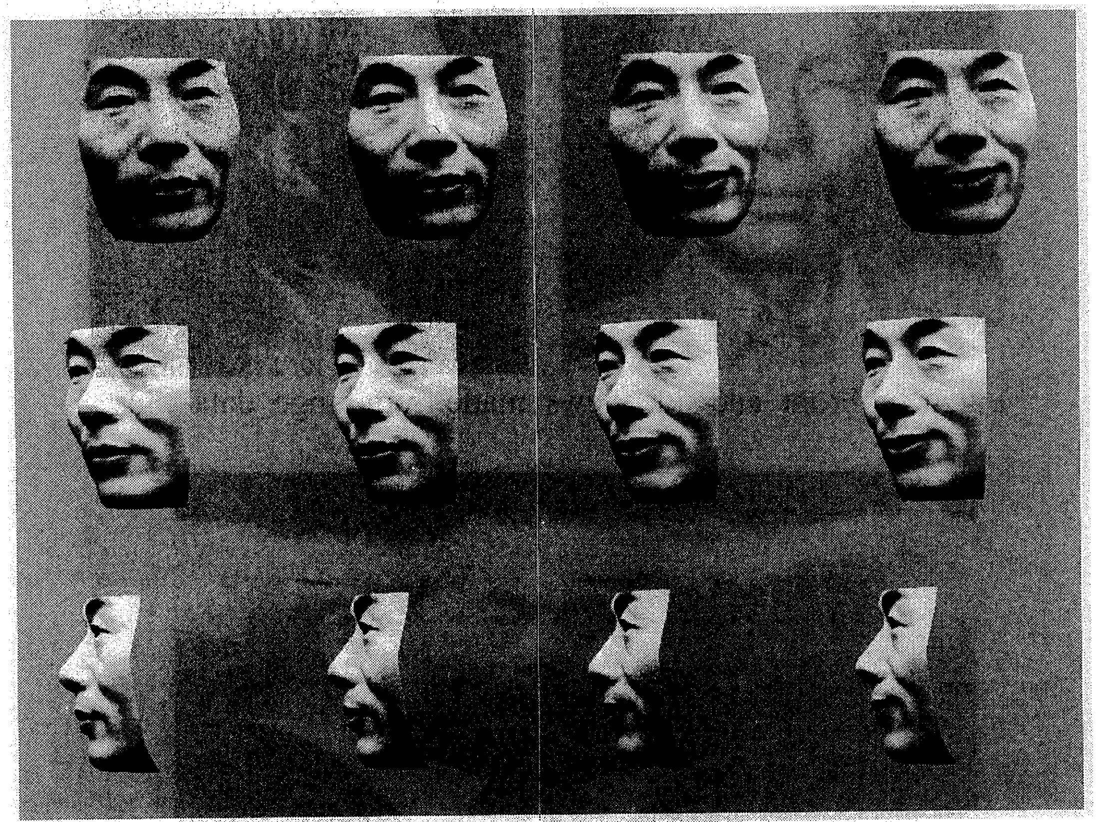

Fig.5　3D facial animation using the data acquired by the method.