

## DEVELOPMENT OF REAL TIME 3D MEASUREMENT SYSTEM AND SYNTHESIS OF RANGE IMAGES WITH VIDEO IMAGES

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### ABSTRACT

We have developed a new type of 3D measurement system which enabled us to obtain successive 3D range data at video rate with an error within  $\pm 0.3\%$

In this paper, we try to reconstruct realistic colored 3D surface model and 3D animation of the moving target from range images obtained by our 3D measurement system. At first, although we used ordinal CG techniques such as smoothing, shading, mapping and so on, the result is not sufficiently good. So, in this paper, we try to synthesize video images with range images obtained by our system. To this aim, a video camera is fixed on our 3D measurement system and takes video images synchronizing with 3D measurement by our system. The measured 3D points are mapped onto the respective video images by means of the coordinate system transformation from coordinate system of 3D measurement system to that of video camera and perspective transformation. Then, color, brightness and so on of the corresponding pixel are attributed to the mapped measured 3D point. Finally, the realistic colored 3D image and animation are reconstructed through the texture mapping technique.

### 1 INTRODUCTION

Recently, computer graphics(CG) is used in not only movie and TV commercial but also field of digital arts and so on and has been widely applied for expression technique of information. But it is hard to deal with CG, because it requires much effort to input the 3D data by manual, and we need expertise yet on making CG.

While, there is strong interest in obtaining 3D data at real time for the purpose of application of computer vision, engineering, medicine, apparel design and so on. In such situation, real-time 3D measurement system has greatly improved and become applicable(Araki et al., 1991)(Araki et al., 1992)(Araki et al., 1995)(Kanade et al., 1991).

In this regard, we developed a high-speed and continuous 3D measurement system which acquires 3D range data successively at video rates (30 scenes per second). If using this system as input device for 3D information of moving target, it may be possible to reconstruct realistic 3D CG and animation of existent objects briefly.

From such viewpoint, we have been trying to make realistic 3D CG of existent human face from successive 3D range images obtained by our system using ordinal CG technique. Although our result is almost satisfactory, there remains somewhat problem in texture and color(Fujita et al., 1995).

In this paper, we try to reconstruct realistic colored 3D surface model and 3D animation of the target from range images obtained by our system. To this aim, a video camera is fixed on our system and takes video images, synchronizing with 3D measurement by it. Then, we synthesize thus obtain 3D images and respective video images by coordinate system transformation and perspective transformation. Finally, the realistic colored 3D image and animation are reconstructed.

### 2 CONFIGURATION OF SYSTEM

#### 2.1 Outline of High-Speed and Continuous 3D Measurement System

Schematic diagram of our 3D measurement system is illustrated in Figure 1.

It is based on slit-ray projection method. The remarkable feature of it is mainly comes from its image plane constructed by PSD array which is horizontally non-divided and linear, where as vertically divided in numbers. By the virtue of this configuration of image plane, the basic datum for 3D measurement are acquired during only one scanning of the slit-ray at high-speed and continuously. This system makes us possible to obtain the successive 3D range image of  $128 \times 128$  spatial resolution at video rates with an error within  $\pm 0.3\%$ . Details of our system is available elsewhere(Araki et al., 1991)(Araki et al., 1992)(Araki et al., 1995).

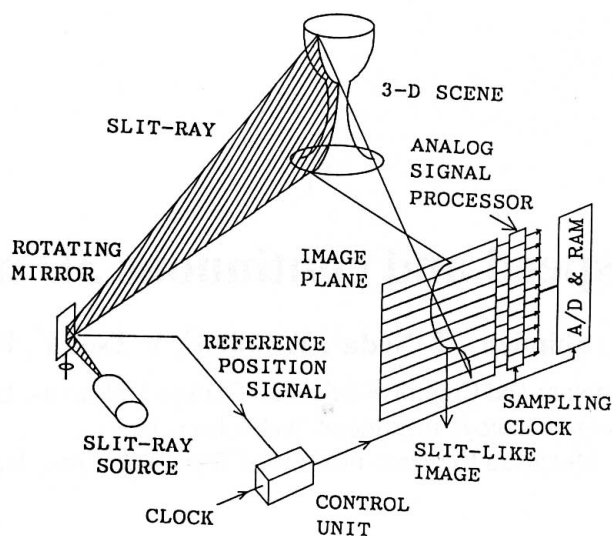


Figure 1: Schematic diagram of high-speed and continuous 3D measurement system

## 2.2 Configuration of System

In this paper, video camera  $V$  is fixed near the 3D measurement system  $M$  as shown in Figure 2. And they are located in such a manner that vertical axis of cameras are parallel to each other so that we can execute the system calibration easily.

Coordinate system of 3D measurement system  $O_M - X_M Y_M Z_M$  and that of video camera  $O_V - X_V Y_V Z_V$  are shown in Figure 2. Now, in this paper, the coordinate of origin  $O_V(V_X, V_Y, V_Z)$  expressed by coordinate system of 3D measurement system and angle  $\theta$  between both cameras are predetermined.

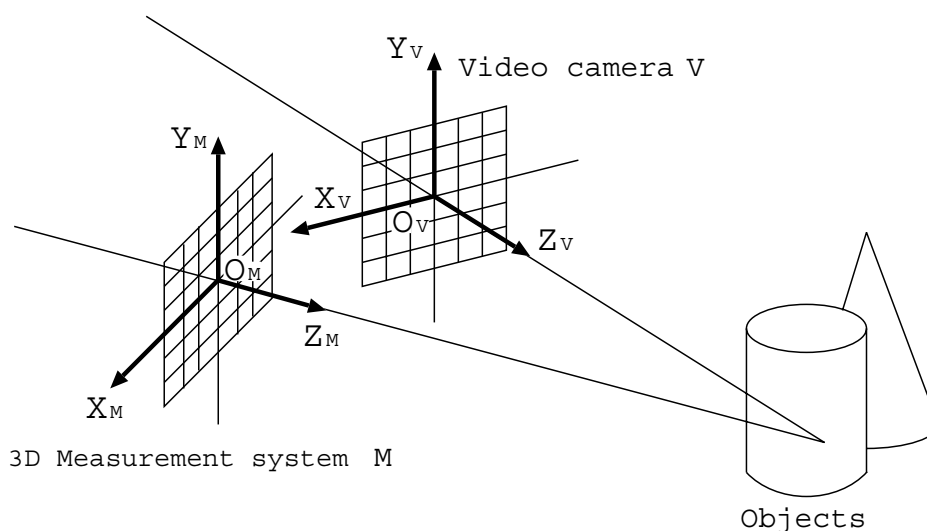


Figure 2: Configuration of system

Figure 3 shows configuration of our systems. Video camera is fixed on high-speed and continuous 3D measurement system. We suppose that the target is located among 550mm to 650mm, so we configure optical axis of video camera is toward point  $R$  whose coordinate is  $(0, 0, 600)$  in the coordinate system of 3D measurement system, as shown in Figure 3.

Thus, visual field of both video camera and measurement system are almost same and so information of most pixels in video image is available.

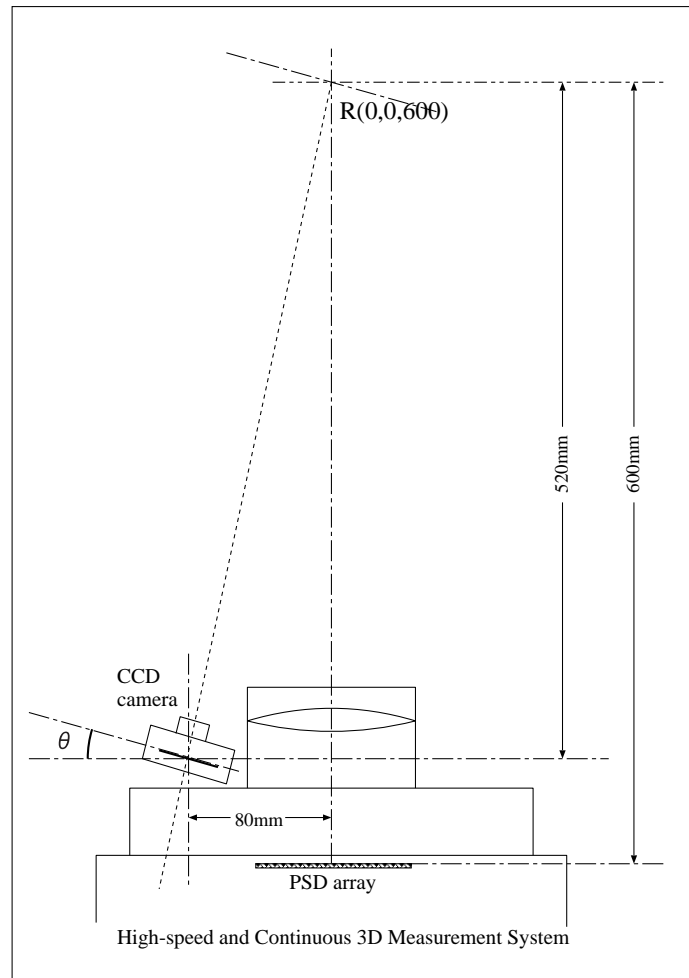


Figure 3: Configuration of measurement system and video camera

### 3 SYNTHESIS OF RANGE IMAGE AND VIDEO IMAGE

#### 3.1 Technique of Position Matching

Position matching of video images with range images is executed as follow.

*Process 1:* Measured 3D points obtained by our system are transformed to coordinate system of video camera through the coordinate system transformation.

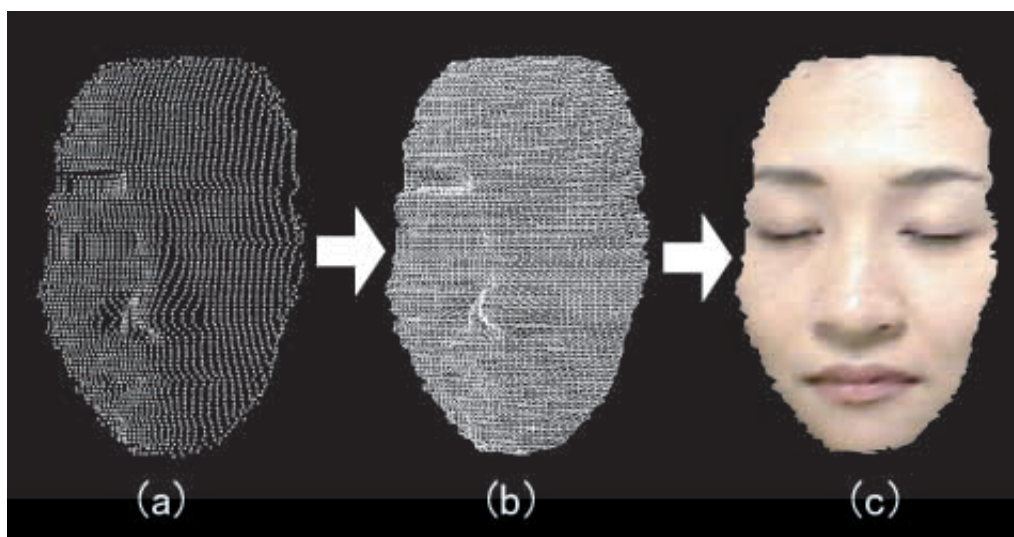
*Process 2:* Measured 3D points represented by coordinate system of video camera in preceding process are mapped onto respective video images by perspective transformation with parameters of video camera.

By carrying out above two processes for all measured 3D points, position matching of video and range images are completed. Then we can attribute the information(color, brightness and so on) of each pixel to the respective measured point. Above processes are formulated as follow.

Transformation from the coordinate system of measurement system to that of video camera is expressed by Equation (1).

$$(X_V, Y_V, Z_V, 1) = (X_M, Y_M, Z_M, 1)T_1T_2 \quad (1)$$

Where,  $(X_M, Y_M, Z_M)$  is the 3D coordinate of the measured point in the coordinate system of measurement system and  $(X_V, Y_V, Z_V)$  in that of video camera.  $T_1$  and  $T_2$  is the  $4 \times 4$  transformation matrix expressed as in Equations(2) and (3) which represent translation and rotation, respectively.



Figures 4: Process flow of rendering

$$T_1 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -V_X & -V_Y & -V_Z & 1 \end{bmatrix} \quad (2)$$

$$T_2 = \begin{bmatrix} \cos \theta & 0 & \sin \theta & 0 \\ 0 & 1 & 0 & 0 \\ -\sin \theta & 0 & \cos \theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (3)$$

Equation for perspective transformation matrix, which represents perspective projection of measured 3D points onto image plane of video camera is given by Equation (4).

$$T_3 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1/p \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (4)$$

Where  $p$  is perspective parameter to be calibrated.

By combining above four equation, the coordinate of mapped measured 3D point  $(X_p, Y_p)$  is expressed by Equations (5) and (6).

$$X_p = \frac{p((X_M - V_X) \cos \theta - (Z_M - V_Z) \sin \theta)}{(X_M - V_X) \sin \theta + (Z_M - V_Z) \cos \theta + p} \quad (5)$$

$$Y_p = \frac{p(Y_M - V_Y)}{(X_M - V_X) \sin \theta + (Z_M - V_Z) \cos \theta + p} \quad (6)$$

Therefore, information of pixel at  $(X_p, Y_p)$  in video image is attributed to respective mapped measured 3D point.

### 3.2 Synthesis of Range Image And Video Image

In general, range image obtained by 3D measurement system is digital image composed from discretely sampled points and so information between sampled points are lacked. We overcome this problem by texture mapping technique.

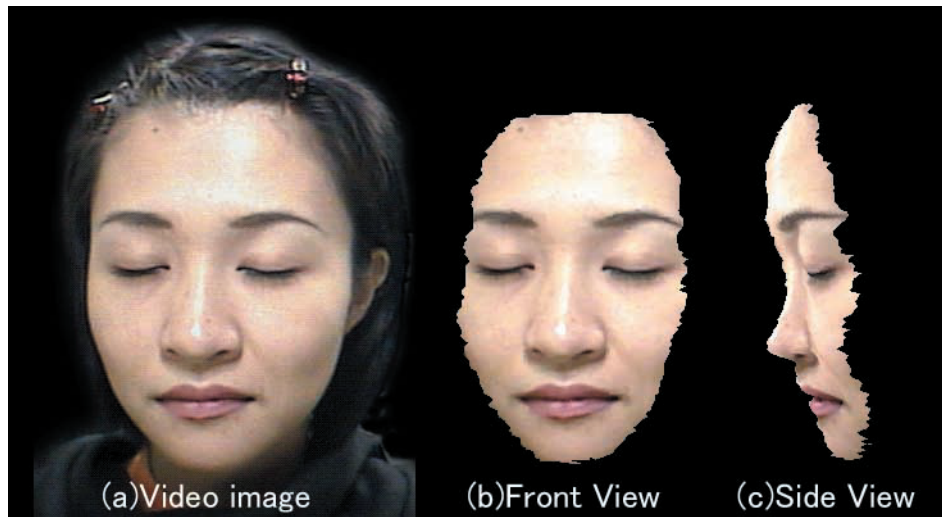
In general, texture images are distorted by 3D shapes. But spatial resolution of our system is so high that above mentioned distortion is little. In this connection, Figures 4 show (a) measured shape data as it is, (b) approximated result by triangles and (c) rendered result by texture mapping technique.

Figures 5 (a) show video image of existing human face, (b) front view of and (c) side view of measured range image rendered through the method in this paper. Figures 6 shows a series of 3D animation of speaking human face picked out from 32 scenes reconstructed from successively measured range images.

## 4 CONCLUSION

In this paper, we tried to synthesize video images and successive range images obtained by high-speed and continuous 3D measurement system and to reconstruct realistic colored 3D surface model and 3D animation.

In synthesizing, 3D points are mapped onto respective video images through simple coordinate system transformation and perspective transformation. Then we can obtain realistic 3D surface model and 3D animation through texture mapping technique briefly. In future, these method can be applied not only CG but also motion capture etc.



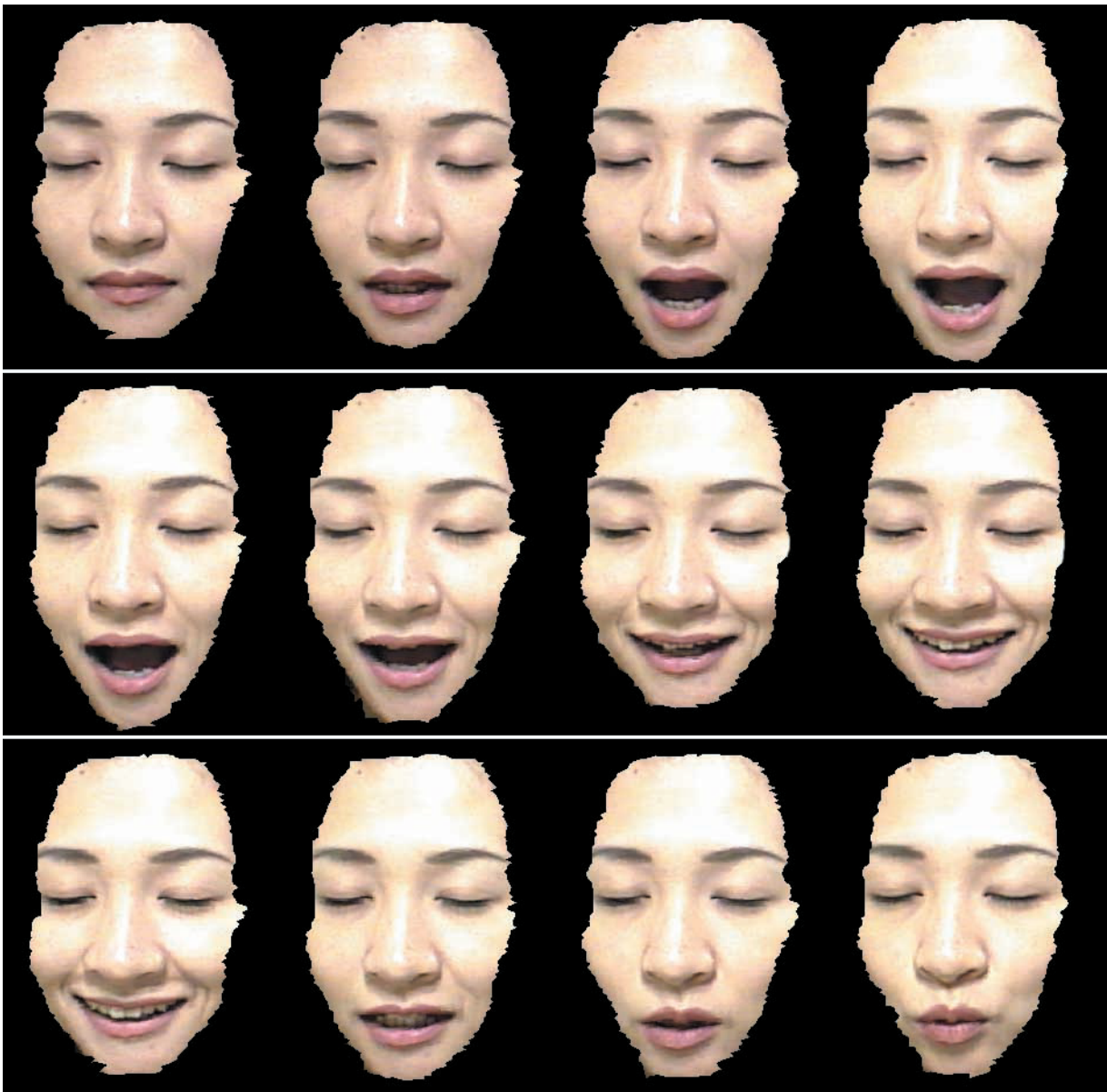
Figures 5: Result of colored 3D image

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Figures 6: A series of 3D animation for a speaking human face, picked out from 32 scenes

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