§49. Virtual Laboratory by Immersive Projection Display

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This research is about 3D shape representation of detailed shape models for immersive virtual systems. One of the goals of our study is to implement virtual laboratory for psychological experiments. In the system, an effective and efficient way of the shape representation has been required in order to establish experiments using photorealistic objects such as face model reconstructed from 3D point measurements. The shape modeling method based on implicit surface representation has become an indispensable technique yielding fast and accurate modeling from massive amount of points on a surface. The modeling technique has meant that surfaces of real objects can effectively be modeled using 3D scanning systems. Color information of the measurements can also be acquired with specific device and it enables surface modeling of human faces with textures.

We suppose here that surface of a 3D object is represented as an implicit function as follows:

$$f(\boldsymbol{x}) = 0, \quad \boldsymbol{x} = [x, y, z]^{\mathrm{T}} \in \mathbb{R}^3,$$

where f is a field function whose value is positive inside the surface and negative outside the surface. Several techniques have been developed for creating field function interpolating measured point data $\boldsymbol{x}_1, \ldots, \boldsymbol{x}_n$. The recently introduced multi-level partition of unity (MPU) method[1)] provides high accurate implicit surface from large number of points with small computational cost. The corresponding color field functions:

$$\left[f^{(\mathrm{R})}(\boldsymbol{x}), f^{(\mathrm{G})}(\boldsymbol{x}), f^{(\mathrm{B})}(\boldsymbol{x}) \right], \quad \boldsymbol{x} \in \mathbb{R}^3$$

can also be constructed from color information defined on the points

$$\boldsymbol{c}_1, \ldots, \boldsymbol{c}_n \quad (\boldsymbol{c}_i = [r_i, g_i, b_i]^{\mathrm{T}})$$

in the same way as the surface reconstruction process[2)]. Some parameters are required in creating the surface and color fields and should be chosen appropriately. The parameters for convergence criteria, which determine the accuracy of the reconstruction, are particularly important since CPU time and memory requirement depend strongly on these values. Let $\varepsilon_0 > 0$ be the convergence criterion for the surface and $\varepsilon_0^{(\mathrm{COL})} > 0$ be that for the color fields. We assume that the coordinates of the points are in a unit cube and that the colors are represented in the full color RGB system with range $[0,1]$. Fig. 1 shows an example of measurements of human face. This was obtained using 3D image capture (NEC Danae100). Note that the scanning system gives points only on the adverse side so some modifications are required so that the points are on a closed surface. For this purpose we also developed and implemented a method to generate additional points on its back side automatically.

The results of the reconstruction for several convergence criteria are shown in Fig. 2. The CPU times in this figure denote elapsed time required for the construction of $f(\boldsymbol{x}), f^{(\mathrm{R})}(\boldsymbol{x}), f^{(\mathrm{G})}(\boldsymbol{x})$ and $f^{(\mathrm{B})}(\boldsymbol{x})$. This indicates that the criteria lead to a trade-off between the quality of the reconstruction and computational costs. This suggests that the parameters should be selected depending on requirements of practical applications.

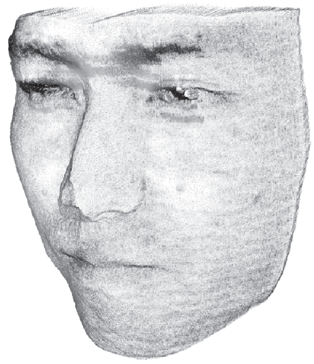


Fig. 1. Example of measurement with colors (344288 points)

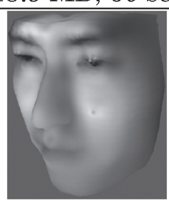
	$\varepsilon_0 = 1.0\times10^{-4}$	$\varepsilon_0 = 5.0\times10^{-2}$
$\varepsilon_0^{(\mathrm{COL})} = 2.5\times10^{-3}$	 28.7 MB, 70 sec	 13.3 MB, 54 sec
$\varepsilon_0^{(\mathrm{COL})} = 1.0\times10^{-2}$	 18.9 MB, 60 sec	 2.6 MB, 44 sec
$\varepsilon_0^{(\mathrm{COL})} = 4.0\times10^{-2}$	 16.5 MB, 51 sec	 0.3 MB, 35 sec

Fig. 2. Reconstruction of surface with color fields for several convergence criteria

Reference
1) Ohtake, Y. et al.: ACM Trans. Graph., **22**, (2003) 463
2) Itoh, T. et al.: ICNAAM 2005 proc., WILEY (2005) 263