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[54] **PORTABLE 3-D SCANNING SYSTEM AND METHOD FOR RAPID SHAPE DIGITIZING AND ADAPTIVE MESH GENERATION**

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[52] **U.S. Cl.** **359/216**; 359/196; 359/17; 359/18; 250/559.22; 356/376

[58] **Field of Search** 359/17, 18, 196, 359/197, 216, 217, 218, 219; 356/376; 250/559.22, 559.23

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,238,147	12/1980	Stern .	
4,297,034	10/1981	Ito et al. .	
4,357,070	11/1982	Fukushima et al.	439/287

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

1295039	1/1992	Canada .	
1332633	10/1994	Canada .	
0 632 349 A1	1/1995	European Pat. Off. .	
4-110707	4/1992	Japan	356/376
2264601	9/1993	United Kingdom .	
2264602	9/1993	United Kingdom .	
WO 96/06325	2/1996	WIPO .	

OTHER PUBLICATIONS

Hoppe, Hugues, "Surface Reconstruction from Unorganized Points", pp. 1–116, 1994.

Eck, Matthias et al., "Multiresolution Analysis of Arbitrary Meshes", pp. 1–25.

DeRose, Tony et al., "Fitting of Surfaces to Scattered Data", 6 pages.

Hoppe, Hugues, "Generation of 3D Geometric Models from Unstructured 3D Points", 4 pages.

Turk, Greg et al., "Zippered Polygon Meshes from Range Images", 4 pages.

Rioux, Marc et al., "White Laser, Synced Scan," *IEEE Computer Graphics and Applications,* vol. 13, No. 3, pp. 15–17 May 1993.

Carlbom, Ingrid, et al., "Modeling and analysis of empirical data in collaborative environments" *Communications of the ACM,* vol. 35, No. 6, Jun. 1992, p. 74. .

(List continued on next page.)

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[57] **ABSTRACT**

A portable 3D scanning system collects 2D-profile data of objects using a combination of a laser-stripe positioning device and a video camera which detects the images of the laser stripe reflected from the object. The scanning system includes a laser-stripe generator, a video camera, a scanning mirror attached to a continuously rotating motor, an encoder or a photodiode operationally coupled to the motor, and associated electronics. As the rotating, scanning mirror reflects the laser stripe and variably positions the laser stripe across the object, the encoder or the photodiode generates signals indicating the angular position of the mirror. The video images of the reflected laser stripes are stored on a storage medium, while data relating to the angular positions of the laser stripes recorded in the video images are simultaneously stored on a storage medium. A computer subsequently synchronizes and processes the recorded laser stripe data with the angular-position data to generate a 3D model of the object by applying triangulation calculation and other post-scanning methods, e.g., multi-resolution analysis and adaptive-mesh generation. The multi-resolution analysis, which applies more points to resolve fine details and fewer points for smooth regions of the objects, leads to significant data compression. The adaptive mesh, which include connected polygonal elements and which may have multiple resolutions and tolerances, is generated by the adaptive-mesh generating routine.

57 Claims, 13 Drawing Sheets