Mensuration of Body Shapes Using an Automated Photogrammetric Approach

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ABSTRACT

A study, to analyze various techniques of recording human body surfaces automatically, was undertaken. This Paper describes the photogrammetric procedure used, accuracies, and system thruput. A comparison of accuracies and thruput for various photogrammetric techniques, and Real Time surface measurement is examined. Also discussed, is the implementation in realistic terms, systems capable of handling a large volume of subjects.

INTRODUCTION

There are numerous techniques available to acquire three dimensional information for human body shapes. However with the development of solid state sensors and scanners the process of measuring body surfaces has been automated.

The recent developments of automated measuring techniques has expanded the areas of applications and insure greater accuracies in determining the final shape. One must consider the various techniques and devices that are available and decide whether they fall under the realtime or semi-realtime data acquisition mode.

G.R.A. over the years have undertaken developments in both areas of realtime and semi-realtime photogrammetry(Robertson,Miles 1984),(Robertson,Wyatt,1984) (Robertson,1986). In most cases Realtime data techniques or devices can be obtrusive, non portable, and actually be too time consuming to effectively measure subjects. Example of this would be measuring topography of patients for radiotherapy or handling large number of patients or subjects. It is for the above reasons the author had undertaken research to develop techniques to not only effectively decrease the time required for the initial data acquisition stage but to the final system throughput for 3D measurements.

BACKGROUND

G.R.A. was part of a research project to study various techniques used in the acquisition of 3D human body shapes. Six systems were chosen for analysis: Moire, Rasterstereography, Laser scanning, Light sectioning, Integrated shape Imaging system and Sonic digitizing.

The first phase of the study was an accuracy evaluation of the systems. National Research Council of Canada standard object form for Moire (Figure 1.) and a head form was sent to our facility in California.

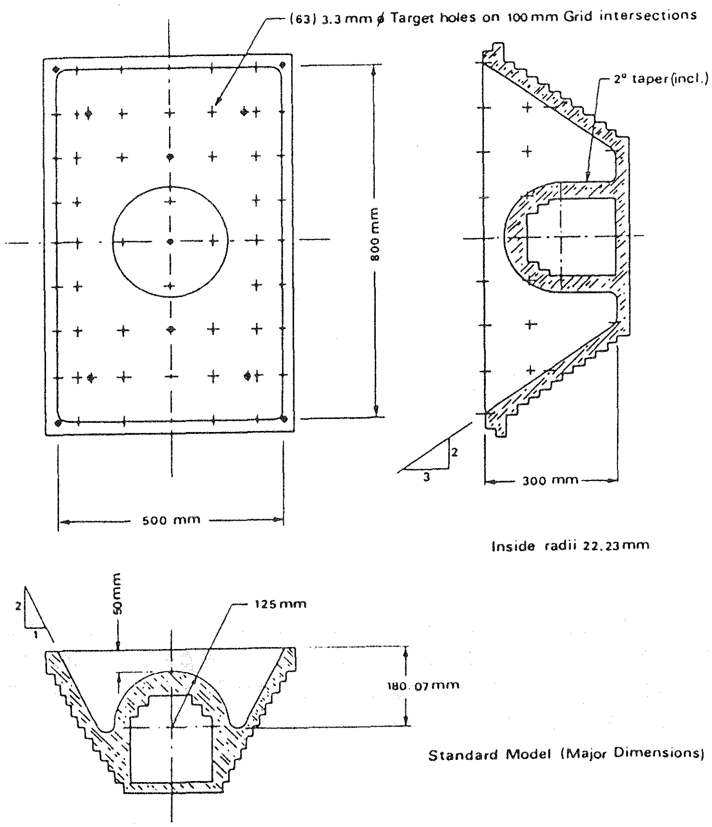

Figure 1. Standard Model Form

For the projected dot and grid patterns several sizes were considered. A grid pattern of 600 and 400 micron spacing and a dot pattern of 300 and 400 microns were used for the test. The patterns were inserted into a standard 35 mm slide mount and projected onto the NRC standard object form and face form with a standard 35mm projector. The above pattern size provided a adequate coverage and density as seen by Figure 2. and 3.

The NRC form and the face form were photographed with a 35mm Olympus camera, all data acquisition was acquired using the 35mm camera. We had chosen an off the shelf non-metric camera for several reasons.

1) - show capabilities of using inexpensive standard cameras.
2) - the accuracies would be more than adequate using 35mm.
3) - show overall portability of the process (camera and standard projector).
4) - easy set up time for walk thru frame for measuring entire body surface.(Figure 4)

The photography was multiple convergent of the mould and face form with the raster used as a subsequent photo in one test, then only as a projected target pattern on the object.

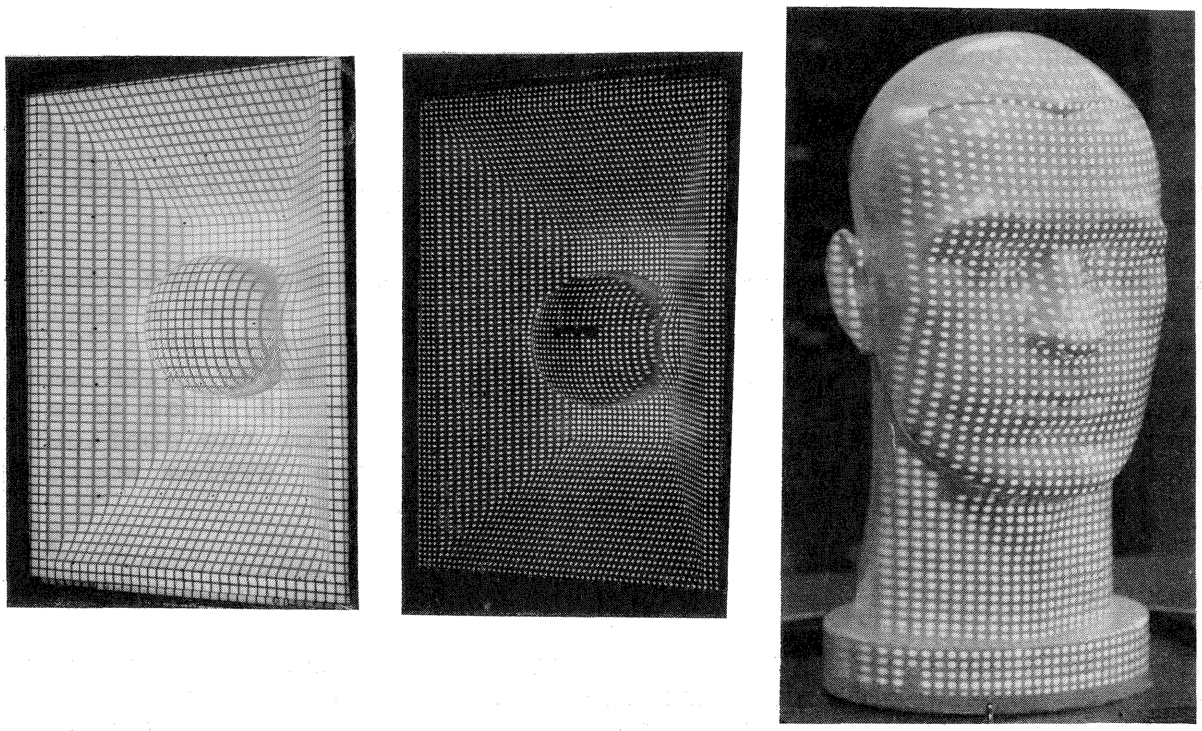

Figure 2. and 3. NRC standard object and Head form

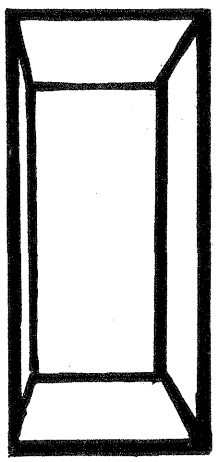

Figure 4. Frame for full body measurement.

DATA REDUCTION

For the data reduction phase a GRA Pass 2000 system was used to read the 35mm frames. A CCD and PMT (photo multiplier tube) detector was used to scan the negatives. The Pass 2000 system has been described in earlier papers (Robertson,Wyatt 1984)(Roberton 1986) The system has measuring accuracies within the .5 micron range and can read a target in less than 1 second.

Although this seems to have adequate throughput the author wanted to test the feasibility of faster thruput, the answer was to test with a lager scanning window and to compute a centroid of every targeted point within the window accurately and within the same time frame. This concept was tested with the CCD and the PMT detectors. The modified Perkin Elmer Microdensitometer

PMT allows for an adjustable scanning window but scans at a pixel per pixel basis which is relatively slow, also for measuring body surfaces the accuracies and geometrically-correct photo images acquired from the PMT based system is not required.

An additional face form was recorded this time with a Rollei 6X6 cm camera and auto scanned see Figures 5 and 6.

A new scanning system was discussed by the author at the commission V symposium in Ottawa, Canada. The basic system a smaller device than the Pass 2000 has a stage size of 23 X 28 cm. scanning area utilizing a solid State area array with basic digitizing rate at 250,000 pixels per second. Scan area is operator selectable in 6 to 12 mm increments. For the configuration of the system for body surfaces the system would be configured for multiple processing capabilities.

RESULTS

All data scanned of the NRC standard object and face form was sent to Biokinetics and Associates Ltd. Bioengineering consultants in Ottawa, Canada for evaluation. Table 3 shows the accuracy of the various systems for the NRC standard object. Each systems operating requirements are shown in Table 1. and Table 2.

Technique	Known Length (mm)	Measured Length (mm) Min.	Mean	Max.	% Dev.	Sample Size
Raster	X = 800 ± .10	799.49	799.81	800.17	0.02	5
	Y = 500 ± .10	499.88	500.04	500.16	0.00	7
	Z = 295.1 ± .10	294.35	294.94	295.33	0.02	5
ISIS	X(1)	-	-	-	-	-
	Y(1)	-	-	-	-	-
	Z = 300 + .03 - .13	237.37	256.04	271.68	14.60	25
Sonic	X = 800 ± .10	797.50	798.80	800.20	0.10	9
	Y = 500 ± .10	499.80	500.09	500.5	0.01	9
	Z = (2) -	-	-	-	-	
Laser	X = 800 ± .10	-	799.85	-	0.18	1
	Y = 474.3 ± .10	471.50	473.61	474.94	0.14	3
	Z = 300 + .03 - .13	299.07	300.14	301.09	0.05	6
Moire	X = 800 ± .10	793.27	797.04	798.32	0.30	4
	Y = 500 ± .10	497.20	500.50	502.42	0.10	5
	Z = 188.7 ± .10	194.50	194.65	194.80	3.00	3

(1) Data loss due to shadows

(2) Data distorted by reflections

Table 3. Accuracy

TABLE 1: SYSTEM COMPARISON

SYSTEM	ACCURACY 1	HARDWARE COSTS 2	MANPOWER OPERATING REQUIREMENTS		FULLY AUTOMATED	SPEED OF IMAGING	INABILITY TO 6 MONITOR	PORTABILITY
			SKILL 4	TIME (MIN)5				
Raster	Good	Very expensive	2	45	Yes	Seconds	A,B	Good
Moire	Adequate	Inexpensive	2	140	No	Seconds	A,B,C,D	Fair
ISIS	Poor	Moderate	0	20	Yes	1.5 sec	A,B,C,E,D	Good
Laser Scan	Good	Expensive 3	1	25	Yes	2 sec - 10 min	A,D	Poor
Light Sectioning	Undetermined	Expensive	1	10	Yes	1.2sec, 2sec, 3min	A,B,D	Poor
Sonic	Poor	Moderate	1	96	No	10+ min	E	Good

1 Good - 1mm <
Adequate - > 1mm
3mm <
Poor - > 3mm

2 Inexpensive - 25,000 <
Moderate - 25,000 - 50,000
Expensive - 50,000 - 100,000
V Expensive - > 100,000

3 Cost for track system not included

4 Little skill - 0
Semi skill - 1
Skilled labour - 2

5 Approximate time required for single object measurement

6 A - Under hair
B - In orifices
C - In shadows
D - In confined spaces
E - due to noise or reflections

TABLE 2: SYSTEM COMPARISON

SYSTEM	SIZE OF FIELD	IMAGE REPRESENTATION	HUMAN BODY REGION MEASURED	EXISTING SYSTEM APPLICATIONS	GROUPS
Raster	Unlimited	Planar Surface [7]	Full body	Experimentally on humans	Robertson Photogammetry Inc. Los Angeles, USA Calgary, Ottawa, Canada
Moire	X - 500 mm Y - 800 mm Z - 400 mm	Planar Surface [8]	Back, head	Used clinically for scoliosis screening	- Variety of hospitals & scoliosis clinics - U of Vermont Burlington, USA
ISIS	Full body	Planar Surface	Back, face	Clinical monitor shape change in scoliosis	MERU - UBC Vancouver, Canada Oxford metric (UK)
Laser Scan	Upper torso	360 deg cartesian coordinates	Full body, hand, face, upper torso	Experimental on humans	Hymarc Eng. Ottawa, Canada
Light Sectioning	360mm -length [9] 100mm - radius	360 deg cylindrical coordinates	Lower leg, foot	Clinical Research in the creation of prosthesis	Center for Studies in Ageing, Sunny Brook Medical Center Toronto, Canada
Sonic	X - 2 m Y - 2 m Z - 2 m	360 deg cartesian coordinates	Anatomical landmarks,	Anatomical landmarks	Biokinetics, DREO Ottawa, Canada

7 360 deg with mirror backdrop

8 360 deg dual image with reference points

9 foot measuring device

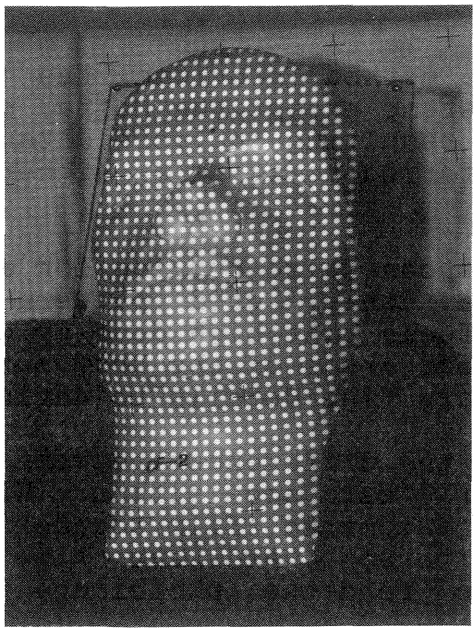

Figure 5. Face form

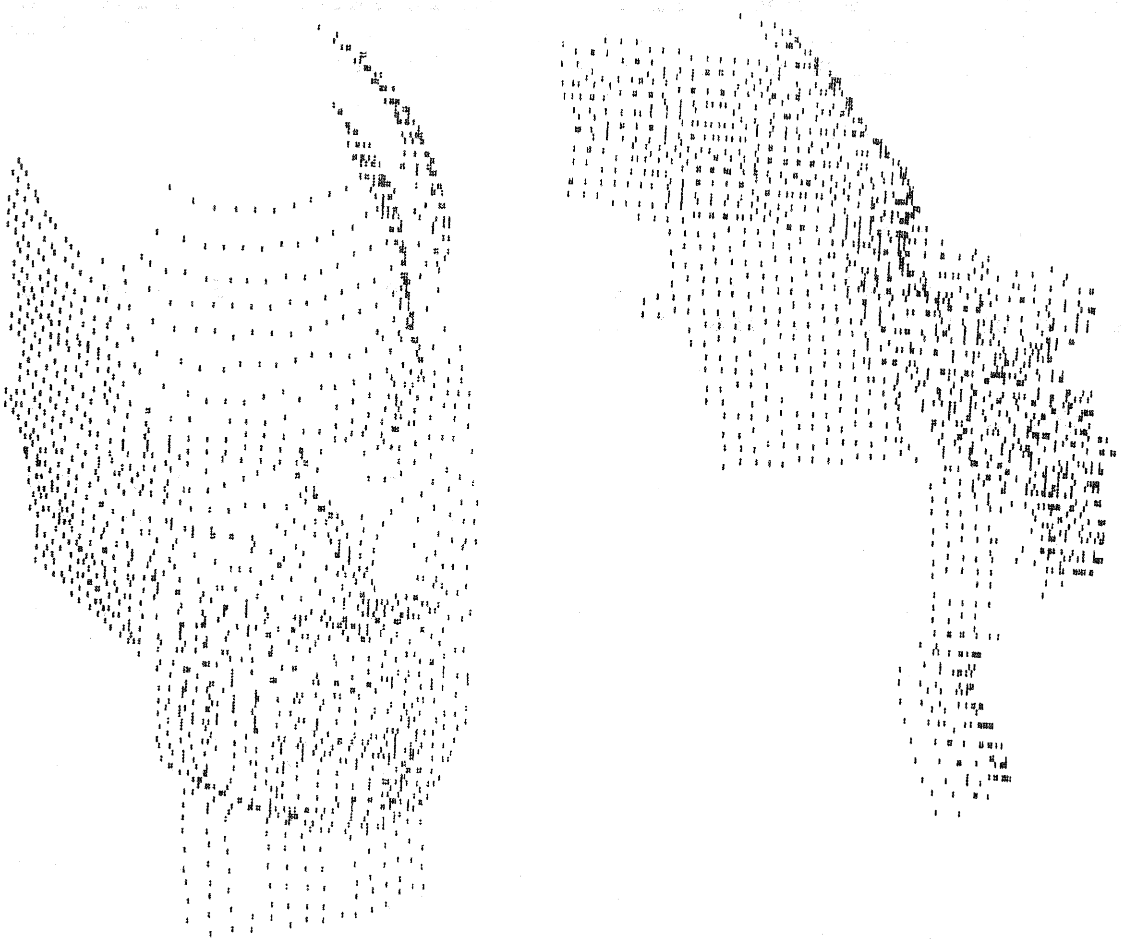

Figure 6.

CONCLUSIONS

Overall the Raster method provided the highest accuracy. Although the other systems except the Moire, provide a constant scan of the surface resulting in more data points on the body surface, some have referred to it as a higher recording resolution.

The raster techniques can also provide for a higher resolution of data points with a denser grid pattern projected on the subject. The author feels that high density grid or dot pattern is not required for most areas of the body but is only effective in areas where there are fine details to define.

One has to consider the differences between realtime and semi-realtime photogrammetric data acquisition. With the development of high resolution automated film scanners and more powerful computers providing thruput at near time rates, it could actually be faster to read the photoimage than it would be to image it in realtime.

The raster or modified raster technique for measuring body shapes is truly portable, speed of recording is dependent only on film speed and illumination. With multiple 35mm cameras and frame an entire body surface can be recorded in less than 1 second with proposed data thruput of 20 minutes. This would enable a large number of subjects to be measured in very little time, utilizing the resolution and accuracy of a conventional photographic image.

ACKNOWLEDGMENTS

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