SINGLE CAMERA DIGITAL PHOTOGRAMMETRIC ANTHROPOMETRY OF INDIAN ADULT MALES

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This paper discusses the procedure and results of single camera photogrammetric anthropometry carried out to deduce 36 body dimensions of Indian males aged between 22 to 50 years. It is a low cost method and can be used widely to carry out a larger anthropometric survey. The paper discusses the complete procedure and errors involved in the process. It elaborates the effective error due to parallax and the technique adopted for its elimination. The effective mean error in the readings was reduced to 0.32 percent. The special application of this low cost photogrammetric technique is to generate planar intra body dimensions which may be required for specific design applications. The results of the photogrammetric anthropometry are compared with earlier anthropometric results augmenting the earlier Indian anthropometric data base.

Keywords: Photogrammetric anthropometry, Indian anthropometric dimensions.

1. INTRODUCTION

In India Anthropometric studies have been done in different pockets. Different Institutes have been involved in anthropometric studies and their interests have varied depending on their own needs and investigational domains. Anthropological Survey of India has been involved in study of Indian anthropometric dimensions but to a very limited extent and all together different perspective than that of design [2]. Other different Institutes have given their contributions to Indian Anthropometry namely the Central Labor Institute, Bombay, Department of Physiology Calcutta University, Defense Institute of Physiology and Allied sciences, Delhi, National Institute of Occupational health, Ahmadabad, National Institute of Design, Ahmadabad and Industrial Design Centre, IIT Bombay. In Indian Anthropometric dimensions [1] Debkumar Chakrabarti has compiled a data on Indian population aimed towards use by designers of furniture etc. This is the only data readily available off the shelf. Most of the reported Indian anthropometric studies have followed conventional anthropometry practices. Photogrammetric approach to anthropometry has not been reported in the Indian context. This study here takes a different route to Indian anthropometry that is by the photogrammetric technique.

Photogrammetry works with the geometry of the imaging process, it depends on (a) 3D co-ordinates of the object, (b) coordinates of the object in the image i.e. image co-ordinates, (c) exterior orientation of camera or camera positioning, (d) inner orientation that include the geometry of imaging and (e) the additional observations that play an important role in determining the final object dimensions [4]. Various techniques have been used in the process of determining dimensional information from

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photographs which broadly utilize the Wiora model. In India there is limited use of photogrammetry for anthropometry and most of the reported works have used conventional techniques.

This paper reports single camera photogrammetric anthropometry the way it was actually carried out to successfully determine Indian anthropometric dimensions with accuracy.

2. METHOD

The procedure comprised taking digital photographs of subjects in the required pose, using vector image processing software for finding the photographic dimensional details and using these along with the experimental set up geometry deduce the final dimensions. The study of error and its elimination was done to arrive at a least error technique. 40 male subjects were randomly chosen from different parts of India. Circular 13 mm white paper markers were put on subjects with bare (minimal clothing) body. Subjects were asked to stand against the background in different postures; they were then photographed in the required pose as shown in Fig. 1. Markers were put very carefully on the subjects as they are vital in determining accuracy of the final dimension. A physiologist was used to recommend the exact points on the subjects body as defined by the dimensions. Additional data like z distance of various planes (passing through the subject, parallel to the background) in which we want to measure the dimensions was also recorded, while taking the photographs a specially designed plumb line is suspended in the plane to touch the ground. This plumb line helped identification of ground level of each plane in the photograph.

The specialty of Photogrammetric anthropometry is that it is able to generate planar intra body dimensions which cannot be very easily obtained by the conventional method. Two such dimensions are shoulder to front most edge and shoulder to eye horizontal distances in the saggital plane of the human body as shown Fig. 2(a). The overall experimental set up was as discussed below.

2.1. Experimental Setup

Figure 2(b) below shows the schematic of the setup.

It shows the structure has background with a grid, a reference scale of 1000 mm (called back scale) on the background, another scale of 1000 mm exactly in front of the background at a distance of 1280 mm (called the front scale). The subject platform on which the subject is placed is in between the background and the front scale, a digital still camera that is placed at a distance of 12 m from the background is used to take the photographs, the camera was carefully centered using geometry to be exactly in front of the background and opposite to the space where subjects were placed.

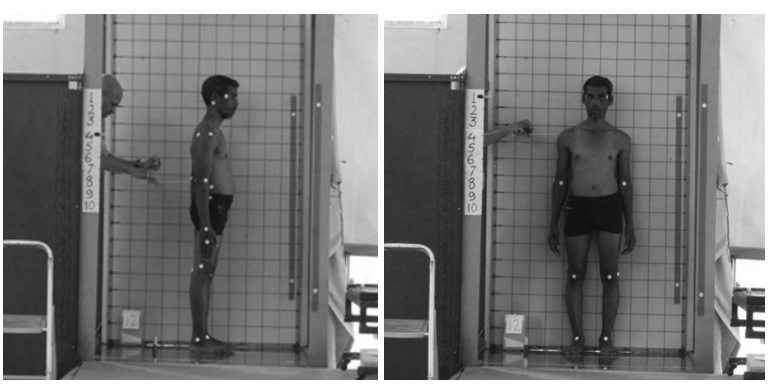

Figure 1. Subject with markers on.

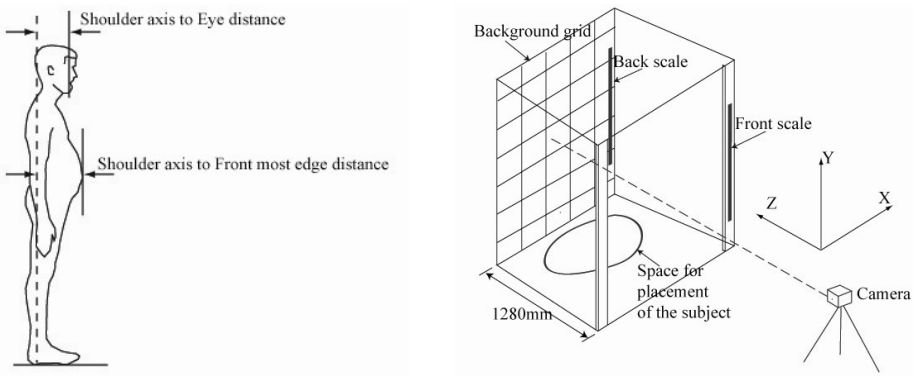

Figure 2. (a) Planar intra body dimensions, (b) Setup Schematic.

2.2. Apparatus

Figure 3 below displays the apparatus that was used for the Photogrammetric anthropometry.

1. The Rig: It is the steel structure designed in such a way that it enables the observer to take three photographs of the subject namely the top, front and the bottom. There are mirrors at 45 degree above and below the subject platform. These mirrors reflect the light to be captured by the cameras. The typicality of this structure is that it has transparent glass flooring on which the subject stands. The subject can be photographed from front, top and bottom, the top and bottom anthropometry has been excluded here.
2. Support frame: A rectangular frame was devised with horizontal nails fitted on to it. This frame could be moved forward or backward thereby varying distance from the background. Also on this frame shifting of the standard scale vertically enabled movement in the vertical direction thereby varying distance from the floor. This arrangement was used to vary distance of the standard scale from background and ground while evaluating error levels and finalizing the method with least error.

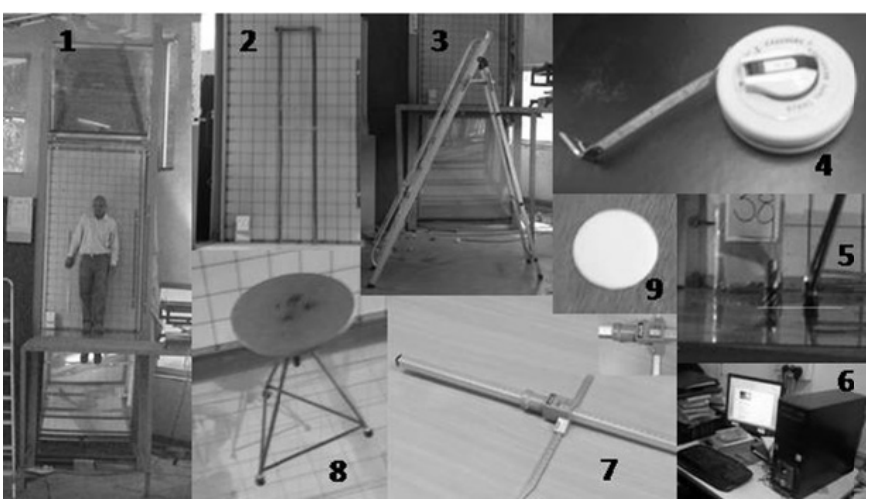

Figure 3. Apparatus used for photogrammetric anthropometry.
1-The Rig, 2-Support frame, 3-Ladder, 4-Measuring tape, 5-Plumb line, 6-CPU, 7-Anthropometer, 8-Sitting stool, 9-Paper Markers.

3. Ladder: A portable lightweight aluminum ladder was used for climbing on to the rig.
4. Measuring tape: A 15 m measuring tape was used to measure large distances especially camera distance.
5. A plumb line specially designed to be used on glass surface was used to mark the point on the ground in the photographs from where distances from ground could be measured. The plumb line was marked with slanting hatched lines so together with the reflection they formed arrow marks. This would work equally good on plane surface photograph (Figure 5).
6. CPU: A PC with Corel software was used for extracting information from photographs. Images of 2272px × 1704px resolution were taken by Fuji Fine pix S5500 digital still camera.
7. Anthropometer: It was used for measuring distances of the subjects various body planes from the background.
8. Sitting variable height stool: A Stool was used for the subjects to sit upon, the diameter of the sitting space was 300 mm and height of the stool could be varied to suit the subjects popliteal height and comfortable sitting posture.
9. Paper Markers: The points on the subject's body, corresponding to various limb lengths from where distances are to be measured were marked using circular paper markers 13 mm in diameter. Using thin double sided sticking tape the markers were stuck on to the subject's body.

Before embarking upon the photogrammetric procedure it was essential to define accuracy of the measuring system. As such an exercise to estimate the error involved in the procedure was carried.

3. ERROR

First stage before the actual measurement process was to estimate and eliminate the errors involved and deduce the accuracy of measuring system. In photogrammetry of this type curvature and perspective parallax errors are predominant.

Figure 4 shows a round object in front of a background. When a photograph is taken the camera does not see the actual diameter b of the object but slightly smaller length b'. This introduces curvature error c in the measurement of the object. Another dominant error is the perspective parallax error p. If we want to measure diameter of this object from the background grid the apparent diameter is b'' which is much larger than the actual diameter b [3]. Both these errors are minimised when the object-camera distance is kept relatively large.

As such the distance of the camera from the background (D) was kept maximum feasible in the experiment space that is 12 m.

3.1. Error estimation

The accuracy has been compared against standard scale. The comparison with conventional method has not been done directly simply for the reason that the variation would only be relative error and

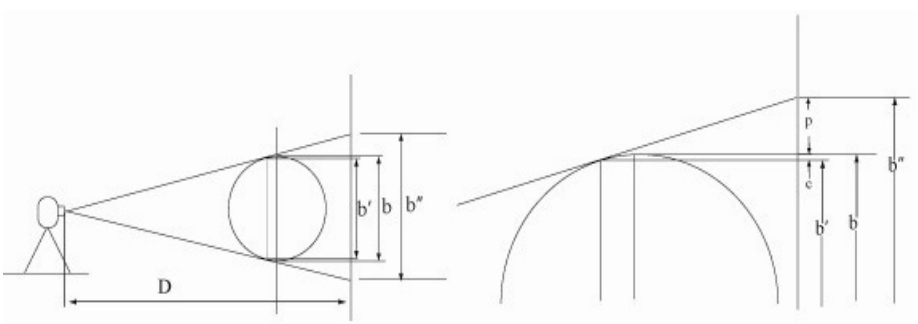

Figure 4. Parallax errors.

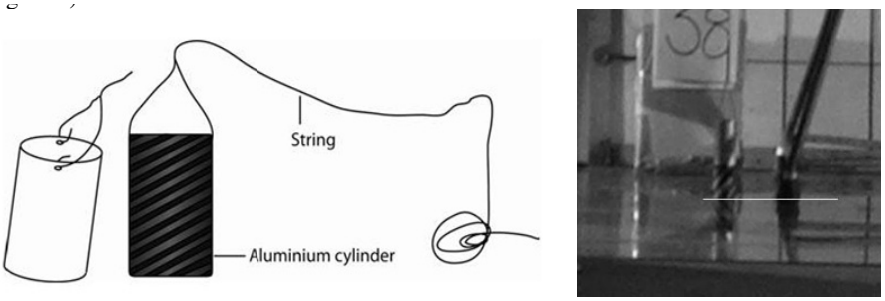

Figure 5. Hatched plumb line.

reflect a summated error in the readings. The variation of photogrammetrically found length from the actual standard length has been estimated as the error in the readings. In the process circular 13 mm markers were applied at both ends of a standard meter scale and this scale was held against the background and photographs were taken. From these photographs length of the scale was measured and error was calculated. This was the ideal state however subject being a three dimensional body which is not in the plane of the background but in space which is in front of the background. So the scale was held at a certain distance from the background using the support frame and photograph was taken. From this photograph length was calculated and a substantial amount of error to the extent of 10 percent was observed. Investigation reveals that the small distances three dimensional bodies have in the z dimension while taking measurement in the x-y plane introduce serious perspective parallax error. Since there is limitation to increasing the distance of the camera from the background an alternative method was sought. For perspective parallax error distance of the measured dimension from the background plane is important. Here a different approach was taken and a plumb line was introduced in the plane of the dimension to be measured. It served two purposes. One that it located distance from the background grid. Second it gave the precise point in the photograph from where vertical distances were to be measured (Figure 5).

Three different methods were evaluated for finding the amount of error in each method. The methods were designed to estimate the final effective error in the measurements.

Method I: One meter scale is fixed on to the background vertical grid (Back Scale). Another one meter scale is attached at front end of the Rig which is at a distance of 128 centimetres from background scale referred to as front scale (Ref schematic Figure 2b). In the photograph of the rig the Back scale is seen shorter than the Front scale due to perspective parallax error (Figure 1).

Photographic length of both the scales is found. The difference between photographic length of Back scale and Front scale is found. This difference is divided by 128 cm to get Parallax error per centimetre from the back ground surface grid. The object to be measured is placed between the BG scale and Front scale. The distance from the background is recorded in cm say z. The product of parallax error per cm and z in cm gives the value of correction to be introduced in the measured dimension. That is apparent dimension minus the correction value gives the correct dimension.

Method II: Object to be measured is placed on the Rig between BG scale and Front scale. Distance of object plane from grid surface is noted say z. Distance D of the camera from the background is noted.

Object dimension is given by $= [(D - z)/D]$.[(Object length in Photograph)/(Scale length in photograph of back scale)] . Actual scale length

Where D is the distance of camera from the background, z is the distance of dimension plane from the background.

Method III: Same as method II except that instead of using Back Scale the known photographic length from the grid corresponding to the length of the dimension to be measured is used thereby every time changing the reference length for every dimension. Method I and II vary in technique of eliminating parallax error whereas III varies for the amount of personal error due to repetitive measurements.

Table 1. Percent errors in the three methods.

	N	Minimum	Maximum	Mean	Std. Deviation
% error with method I	30	0.00	23.00	3.98	5.86
% error with method II	30	0.020	0.98	0.32	0.24
% error with method III	30	0.056	1.55	0.58	0.42

3.2. Error results

On a vertical rigid stick 8 markers were fixed with a spacing of 25 cm, these were different lengths to be used for evaluation named as L2-3, L4-6, L3-6, L3-7, L1-8 implying that they correspond to the distance between those respective points marked by 1,2,3,4,5,6,7 and 8. As such the known lengths were as follows:

L 2-3 250 mm
L 4-6 500 mm
L 3-6 750 mm
L 3-7 1000 mm
L 1-8 1750 mm

Six photographs were taken at a distance of 1 cm, 20 cm, 40 cm, 60 cm, 80 cm, 100 cm from the background called as ercal1, ercal2, ercal3, ercal4, ercal5, ercal6 respectively. All these lengths were calculated using the three methods described above. Results of this procedure are listed above in Table 3.1..

Method II displayed the least error and was adopted to carry out the anthropometry. Maximum error observed is 0.98 percent and minimum is 0.020 percent. The mean error is 0.32 percent. The data on subjects was then collected in the form of digital images. These images were then imported in to Corel and the photographic distances were deduced. The markers could be zoomed-in in the photograph to more than 10 times its actual size and the center of marker could then be easily pin pointed. These dimensions were then fed to Excel sheets and the final dimensions were deduced from calculations.

4. RESULTS

Figure 6 above shows the 36 dimensions that were deduced, final dimensions are given in Table 4.1..

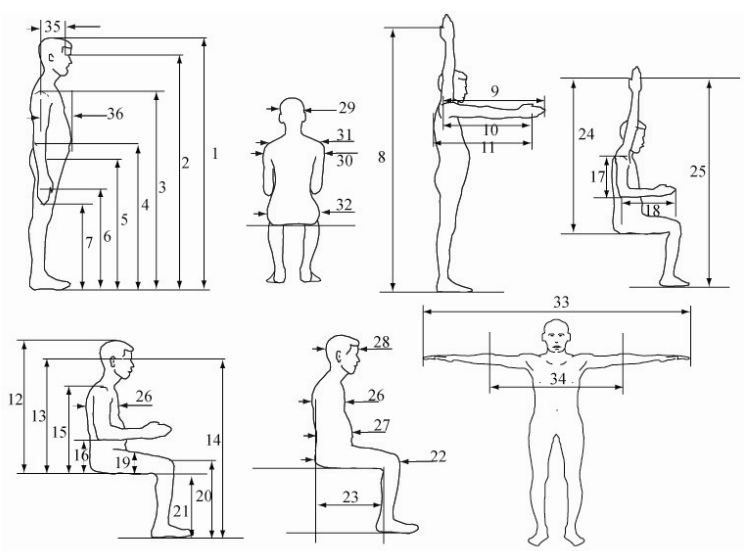

Figure 6. Anthropometric dimensions deduced.

Table 2. Anthropometric data generated by Photogrammetry.

SN	Dimension Name	Min	5th	50th	95th	Max	Mean	SD
1	Stature	1557	1580	1657	1756	1782	1657	54
2	Eye height	1437	1445	1531	1636	1661	1534	56
3	Shoulder height	943	1250	1342	1427	1457	1330	82
4	Elbow height	957	966	1044	1112	1369	1043	67
5	Hip height	846	854	898	980	1035	911	42
6	Knuckle height	641	660	703	755	781	703	33
7	Fingertip height	530	559	606	665	684	610	35
8	Vertical grip-reach (standing)	1869	1876	1991	2123	2180	1998	74
9	Upper limb length	666	689	735	796	808	736	31
10	Shoulder-grip length	577	590	634	684	701	634	29
11	Forward grip reach	678	705	751	800	846	750	34
12	Sitting height	571	797	854	899	919	847	54
13	Sitting eye height	486	660	723	768	780	718	48
14	Sitting eye height from Ground	760	1073	1156	1216	1301	1146	78
15	Sitting shoulder height	499	503	550	614	887	560	61
16	Sitting elbow height	169	180	220	273	303	221	30
17	Shoulder-elbow length	279	292	331	355	370	329	19
18	Elbow-fingertip length	413	423	454	486	623	458	33
19	Thigh thickness	120	134	156	188	193	158	17
20	Knee height	463	478	506	543	554	508	20
21	Popliteal height	375	398	416	461	475	421	21
22	Buttock-knee length	491	527	557	592	611	555	24
23	Buttock-Popliteal length	409	428	452	486	506	455	22
24	Vertical grip reach (Sitting)	1086	1120	1195	1262	1280	1192	50
25	Vertical grip reach (Sitting) from Ground	1155	1517	1608	1712	1750	1606	95
26	Chest(bust) depth	182	193	224	268	383	231	34
27	Abdominal depth	167	180	231	309	328	238	43
28	Head length	181	188	205	220	222	205	10
29	Head breadth	159	161	177	193	201	177	11
30	Shoulder breadth (bideltoid)	377	390	432	485	505	434	29
31	Shoulder breadth (biacromial)	312	316	365	403	418	364	26
32	Hip breadth	315	327	365	411	464	369	31
33	Span	1570	1598	1683	1791	1840	1691	65
34	Elbow span	752	765	837	909	1706	855	144
35	Shoulder-Eye (Horizontal)	82	85	109	139	163	111	19
36	Shoulder–front most edge (Horizontal)	110	116	169	232	256	170	34

Table 3. Comparison of NID(A), IDC(B) and present case(C) data generated by photogrammetry.

SN	Dimension	5^{th} Percentile			50^{th} Percentile			95^{th} Percentile		
		A	B	C	A	B	C	A	B	C
1	Stature (St)	1537	1541	1579	1648	1651	1656	1781	1750	1756
2	Eye height (Eh)	1419	1434	1444	1529	1543	1531	1645	1634	1636
3	Shoulder ht (Sh)	1235	1259	1249	1351	1358	1341	1459	1453	1426
4	Shoulder breadth (Sb) (Bicromial)	341	308	315	380	354	364	422	390	403
5	Buttock-knee length (Bk)	489	500	527	558	540	557	615	591	592
6	Knee height (K)	472	466	478	519	511	506	567	552	543
7	Popliteal height (Ph)	380	400	398	425	432	416	471	468	461
8	Span (S)	1549	1593	1598	1684	1724	1683	1829	1838	1791

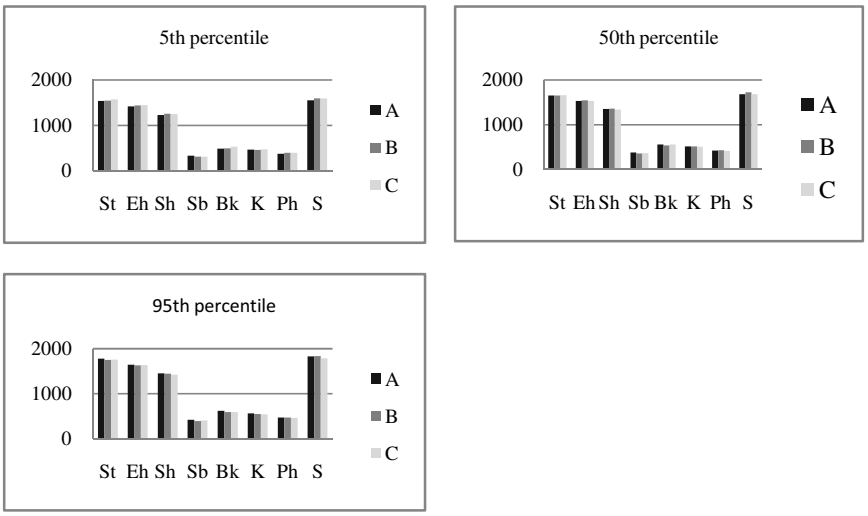

Figure 7. Comparison of the present data(C) with NID(A) and IDC(B) data.

The Stature, Eye height, Shoulder height and shoulder breadth Buttock knee length, Knee height, popliteal height and span are compared with earlier data generated by conventional anthropometry and displayed in the Table 3. The results are comparable and observed to be satisfactory the variation can be attributed to sample size and other factors. The graphs following the table show comparison of the three data in Figure 7.

5. CONCLUSIONS

This exercise provides a basic ground work for carrying out a photogrammetric anthropometry. Since the set up required is easily available the procedure can be applied for carrying out large scale anthropometric survey utilising the advantages that the photogrammetric anthropometry provides. Also before carrying out a photogrammetric anthropometry, it would be very essential to distinctly state the amount of error that could be involved in the measured dimensions. As such the contributions of this work is to

- Detail out a low cost single camera digital photogrammetric anthropometry procedure which can be used for a larger anthropometric survey.
- Generate four additional dimensions adding to the existing anthropometric database of Indian population.
- Minimize and state the amount of error in the procedure of measurement.
- Designers can use this method to generate specific data they need.

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