

An anthropometric survey using digital photogrammetry: a case study in Recife, Pernambuco, Brazil

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Abstract. This study was carried out in a partnership with the Federal University of Pernambuco and the Faculty of Human Motricity of the Technical University in Lisbon (Portugal). The aim of the study was the measurement of human body segments throughout the digital photogrammetry, comparing and analysing data into Recife sample and to validate the Digital System as anthropometric survey tool. The result of the analysis has introduced: Data from the sample; Data by age; Data by Sex; Data by ethnicity; Data by region of birth; Difference of data from population individually. Besides to prove the true efficiency of the software.

Keywords: *Anthropometry, Anthropometric Surveys, Digital Photogrammetry, Digita System*

1. Introduction

Roebuck (1995) [6] states that, technological innovations are changing the extent to which anthropometry is used in engineering applications. Among these innovations are computerized modeling. Modeling people as substitutes for humans living in Computer Aided Design (CAD) applications of ergonomics, and the use of new methods for measuring electronic image. The anthropometric measurement and application methods are currently undergoing a significant revolution in its concepts, as a result of these new technologies.

This development has focused attention on past and current deficiencies in the collection of anthropometric data. Opinions and application of methods have created new demands for more detailed and integrated.

According to Brito and Filho (2003) [2] means the study of photogrammetry for reconstruction of three-dimensional space (space-object) by Two-

dimensional (space-image). In this context emerges the Digita System, a methodology for analyzing static anthropometric, which uses techniques and requirements of photogrammetry. His methodology consists of two softwares, and a program to generate a database and a program of collecting and storing information in a database.

In 2004 the Digita System were available for use in Brazil for teaching and research, among which, the Federal University of Pernambuco showed a greater interest.

Thus, through the Graduate Program in Production Engineering from the Federal University of Pernambuco, we conducted an anthropometric study indicative of a sample of the population of Recife, with the main objective to validate the tool.

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2. The Digital Photogrammetry

According to Ribeiro (2003) [5] Photogrammetry, which emerged in the mid-nineteenth century, more precisely in 1858 in France with Colonel. Laussedat Aimee, who called for "Metrophotografy" has had many advances since then.

During the nineties, however, a great revolution in the world of photogrammetry has been seen. The first fully digital instruments were created, due to advances in computer technology, which allowed real-time manipulation of large raster image files.

The state of the art of photogrammetry is represented today by numerous techniques, digital photogrammetry, which can be described as the automatic reconstruction of space-object in images, using for this, digital images or scanned and computational methods and processes.

According to Araki (2004) [1] photogrammetry allows the determination of position and shape of objects from photographs. In other words, photogrammetry allows reconstruction of objects and determination of some of its features without the need to touch them.

2.1. The Digita System

The Digita provides registration and location of anthropometric landmarks in space, obtained from digital photographs. The location of the joints can be obtained by setting reflective markers (or light diodes issuers) in the body and asking the person who carries out some poses for viewing all the segments of the joint, even in three-dimensional points.

By positioning a digital camera and subject, proceeds to the calibration of a surface of known arrests for the program. This leads to photogrammetric data from all the other distances of the plan.

According to Rebelo (2002) [4], the digit is divided into five steps, which are described below:

- **Step 1: Ergonomic Assessment.** At this stage the analyst should define what will be analyzed. This can be done by applying techniques of interviews and questionnaires, detailed definition of the target audience and others to determine and justify which anthropometric measurements are collected.

- **Step 2: Configuring the Database.** This is the first step in the software itself. Here we must record all data will be analyzed in the next step.

First it is filed in the database that accompanies the official program. This database is inserted into a window.

The program offers two types of fields to fill. The first, with 12 fields, refers to "the categorization of the individual," the researcher should state it up to 12 variables that identify the subjects of the sample. And second, with 42 fields, which should be filled with the anthropometric variables to be collected.

- **Step 3: Realization of Digital Photography.** For this step the researcher must have at its disposal a digital camera to collect digital images.

The software recommends that the digital camera should have a resolution greater than 640x480 pixels, to facilitate the identification of points, even with the image magnification.

The software recommends that carried two photographs of each individual, and a position in front and one in the sagittal plane, except for some peculiarities required in each posture. They are:

1. The individual in the front stance should be with open arms, outstretched hands and fingers together. The legs should be closed and upright.

2. In the sagittal position, the individual must be positioned with its left side toward the camera, you should have your left arm and leg hanging and folded at an angle as close as possible to 90 degrees

To determine the anatomical landmarks of individuals, the researcher can make use of any material to indicate its exact location in the image. Rebelo (2002) [4] states that preference should be given the volumetric markers in order to have visibility of points in different positions.

Another recommendation of the program is that you must establish an optimal distance of 6 meters between the camera and the subject being photographed. For better positioning of the individual, and the quality of the survey, some supporting materials are required upon the completion of digital photographs, namely:

1. 500X500mm Reference: For the distances between the points of the image are recognized by software is required the user to indicate at the beginning of each analysis, a measure known to the system. From those details known, the program can calculate the other points listed in the same plane. To fabricate a solution has to trace the perpendicular bisector of a square with 50 cm edge. This bisector should be designed in a cardboard or other material plan and drive.

2. Graded Posture: In most of the analysis is necessary to place elements to guide the positioning of the subject for example: you can put two sticks as a

guide and instruct you to only lightly touch on this bar.

3. Individual Numbering: Each individual should be numbered to avoid it to be measured more than once. Numbering can be done on a sheet of cardboard or even PVC, which will the information to be erased and changed numerous times.

4. Base Support for the Foot: The subject has to be balanced, this can be done by taking the position determined by a sagittal view, it is necessary for interference from other objects to help support the maintenance of posture for long periods. You can use a stool to support the foot, adding that the leg should be bent as close to 90 degrees as possible.

5. Elastic band around the head: Each individual must be using an elastic band on his head, to allow measurement of the depth and breadth of one (without the hair stop).

- **Step 4: Scanning Coordinate:** At this stage the analyst is using the second software, the type itself. With access to the program of analysis the researcher must fill item by item all information previously set in the database. This is because the menu is organized by objects meaning that the user has to provide the data prior to go to the following information.

In this first screen, is part of the configuration information from the analysis. This information is as follows:

1. Enter the total number of measures to collect. Here researcher reports the number of anthropometric measurements that will be measured. This number was filled earlier in the Configuration section of the database, which limits up to 42 measures.

2. Enter the total number of images collected for each individual. The investigator should inform how many images were captured for analysis of all measures (at least 1 and maximum 4).

3. Indicate when the input image of each grating measurements. At this stage the investigator should inform the program after what extent should replace the original image with another. When you reach the extent determined, the program automatically asks for the second image.

After completing this program will release the first screen to access the next item, also organized by objects. The first refers to the categorization of the individual in this window, the analyst must complete all information identifying the subject of analysis (maximum 12).

After the first indication of the image, the browser opens the second screen, which displays the main window. From then on, you must start the calibration

of the image using the bisector which is on one side of all images.

Then the program requests the first is described as just below the penultimate object. In this case one can use the bars to move the image to see the points that compose the measure requested by the program.

At the end of the measures the program warns that the data should be recorded and the record button is enabled when the button is clicked, a screen appears with the results of the collection, exposing the data segments as well as the personal data collected for the individual who has just to be measured. Then, one must keep up with the same procedures, this time with a new picture.

- **Step 5: Presentation of Results.** In presenting the results the program generates a spreadsheet with all the measurements, separated by groups or classes. The analyst can freely calculate the percentile maximum and minimum of each of the segments analyzed body or each member of the population studied.

The figure 1 shows the main window, where you can see the main stages of the measurement using the Digita System.

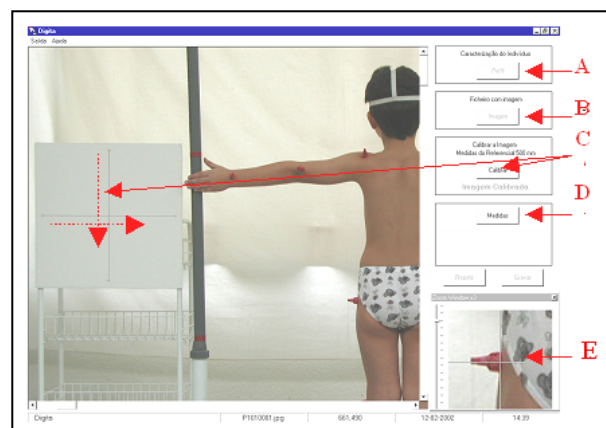


Figure 1: Main window of the program with the following information (left, top to bottom):

- (A) Individual cadastre;
- (B) Indication of the image file;
- (C) Calibration and gauge indicating the direction of 4 clicks;
- (D) Anatomical measurements;
- (E) Magnifier - Zoom with correct indication of the marking points.

3. Field Study

The field study was conducted in accordance with the code of ethics outlined by the Brazilian Association of Ergonomics (ABERGO) and the Ethics

Committee of the Federal University of Pernambuco (CEP / UFPE).

With guaranteed anonymity and confidentiality of information provided, as well as the legal rights of each individual image in accordance with Article 5, sections V, X and XXVIII of the 1988 Brazilian Constitution, reserving the use of data collected only for scientific purposes research.

The survey was conducted with a random sample of 200 individuals in the city of Recife, where the only requirements were that they were aged between 18 and 65, were not physically disabled and residents in Recife. Data collection was preceded on Boa Viagem beach, where there are large movements of people.

To fill the database software, we selected some general data to be collected on individuals surveyed. These data were collected through a questionnaire administered at the time of approach of each individual through these data, we obtained the profile of the sample to the collection of the following:

1. Age: expressed from the date recorded in the identity card;

2. Gender: definition of sex between male and female;

3. Ethnicity: requested from the information given on the birth certificate of each individual, ranging from white, black and brown;

With regard to the selection of measures, an investigation was made of anthropometric variables used in surveys of this type. We analyzed the surveys conducted in 1988 by the National Institute for Technology (NIT) [3] and surveys conducted by the Faculty of Human Kinetics, Lisbon - Portugal, Rebelo (2002) [4].

Anthropometric variables were identified coincident to these surveys, and from these, 19 were selected for survey variables, which are divided into two body plans (frontal plane and sagittal plane) recommended by the program.

Each of the 19 body segments is bounded by an anatomical reference point, this segment of the measurement is by measuring the distance between these points, varying according to the specification of each segment.

Thus we present, in the following table 1, anthropometric variables and body landmarks for each of these variables selected for measurement. These landmarks were used to define the extremes of the body part, facilitating the measurement performed by the software.

Table 1
Anthropometric variables selected and their respective body landmarks.

Body Segment	Body Landmarks
Front Plane	
1. Height	From top of head (vertex) to the ground.
2. Head Width	At opposite ends of the head at the level of Euryon.
3. Shoulder Width (biacromial)	From the left acromion to the right acromion.
4. Chest Width	Among the armpits, from the left terion to the right terion.
5. Width between the hips	Among the major trochanter of the femur. From the left trocanterion laterale to the right trocanterion laterale.
6. Arm Length	From the acromion to the crease of the elbow joint.
7. Forearm Length	Fold the crease of the elbow joint of the wrist joint.
8. Length of the Upper Limb	From the acromion to the end of the middle finger (Quirodátilo III).
9. Eye Height	The average distance between the eye sockets to the ground.
Sagittal Plane	
10. Hand Length	In the wrist joint, wrist joint crease to Quirodátilo III.
11. Hand Width	At the distal end. From the metacarpal I to the metacarpal IV.
12. Shoulder Height	From the acromion to the ground.
13. Hip Height	From The major trochanter of the femur to the ground..
14. Popliteal Height	In the popliteal cavity, popliteal line to the ground.
15. Height of the external malleolus	from the external malleolus of the fibula to the ground.
16. Knee-Ankle Length interarticularis	From the lateral femoral condyle to the external malleolus of the fibula.
17. Head Depth	On the forehead between the eyebrows to the extreme point of the occipital bone.
18. Depth of Chest	At the level of the nipple.
19. Depth of the Abdomen	In the waist, up to the navel.

Each person had his body marked by landmarks with elements of distinction, where they had different color and volume, thereby facilitating the identification of anatomical boundaries of each segment selected for measurement (Figures 2 and 3), these elements were designated as body reference markers.

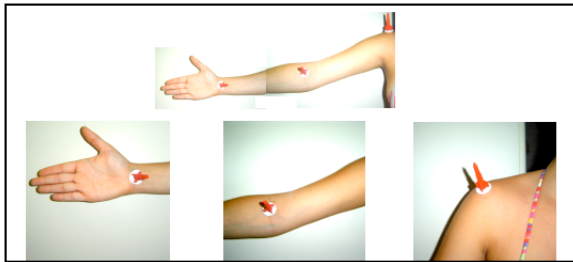


Figure 2: Body marked by landmarks with elements of distinction – Upper Limbs



Figure 3: Body marked by landmarks with elements of distinction – Lower Limbs

It was used as reference marker, children's toys in the form of "rocket". Made of plastic and available in several colors.

It was necessary that each person is wearing as little clothing as possible, were the ideal bathing suits, knitwear close to the body or undergarments, allowing a complete location information and accuracy in identifying the variable and its limits.

Each person was identified with a specific number in the act of photography and this number was exposed on each image. This numbering avoided that the same individual was measured more than once.

Persons who had long hair, had their hair fixed with elastic straps so they do not come to hamper the visualization of an anthropometric variable to be scaled.

We used a reference plane of 500 X 500mm perpendicular to the ground, as recommended by the program.

We established a plane parallel to the plane where the camera was located. Under this new plan, the individual has positioned itself to carry out the shooting.

He set up two rods perpendicular to the floor for the alignment of the arms, as well as the person's body, the plan to be photographed.

Therefore, we present in Figures 4 and 5 an example of digital photographs taken during the field study, exposing both the positions taken and photographed body plans, such as support materials used.



Figure 4: Example of digital photographs collected during the field study - Frontal Plane.



Figure 5: Example of digital photographs collected during the field study - Sagittal Plane.

In the final phase of this step, the data were saved to disk and passed to a new measurement, using a new photo. At the end of the survey, all cataloged data were exported to other software (Microsoft Excel 97), where it possible to carry out statistical analysis charts.

4. Results

Data analysis was carried out in collaboration with the statistical team member of the Graduate Program in Production Engineering from Federal University of Rio Grande do Sul After completion of the analysis, it was possible to establish:

□ The overall results of the survey population - number of persons, mean, variance, standard deviation, coefficient of variation, minimum, maximum,

range, percentiles 2.5, 5, 50, 95, 97.5 and gross frequency histograms and stored.

- The results by age groups in two ways:
 1. Overall results - number of persons, mean, standard deviation, coefficient of variation, percentiles 2.5, 50, 97.5.
 2. Divided by sex - number of persons, mean, standard deviation, coefficient of variation, percentiles 2.5, 50, 97.5.
- Results classified by gender:
 1. Male - percentiles 2.5, 50, 97.5
 2. Female - percentiles 2.5, 50, 97.5
- Intrapopulation differences and characteristics.

Finally, it became possible to configure anthropometric tables on population studied, where each of these was divided into body segments and percentiles for men and women regarding the overall results, age and ethnicity of individuals.

We can see in Table 2 an example of these tables, which present the general data of the sample classified by gender.

Table 2
General anthropometric data classified by gender
(values in mm).

SEGMENTOS CORPORAIS	MULHERES			HOMENS		
	2,5	50	97,5	2,5	50	97,5
Height	1398	1575	1756	1671	1735	1871
Head Width	123	157	176	156	163	183
Shoulder Width (biacromial)	247	311	365	330	359	459
Chest Width	259	317	402	350	377	459
Width between the hips	289	347	423	338	354	422
Arm Length	216	257	295	259	277	318
Forearm Length	197	231	269	243	257	296
Length of the Upper Limb	567	653	734	694	724	789
Eye Height	1291	1468	1656	1561	1623	1742
Hand Length	135	175	204	183	193	222
Hand Width	63	79	89	83	87	102
Shoulder Height	1156	1300	1631	1380	1436	1565
Hip Height	714	800	1012	854	904	1000
Popliteal Height	318	394	459	425	447	495
Height of the external malleolus	41	69	96	68	76	115
Knee-Ankle Length interarticularis	301	354	410	371	390	447
Head Depth	151	185	208	189	198	220
Depth of Chest	181	227	309	224	245	298
Depth of the Abdo- men	163	213	291	209	224	330

5. Discussions

With this study we were able to corroborate some of the advantages of using digital point by Rebelo (2002) [4], related to traditional photogrammetric systems, namely:

To get samples from several points and with high resolution, it is normally necessary to use multiple cameras alongside other expensive and complex equipment complex and expensive. This does not occur in Digita, since it requires only 1 good digital camera and equipment and consumable materials fully adapted by the researcher. Making the cost of this system greatly reduced.

With these traditional systems, lighting conditions must be controlled (there should be no point source of light or glare in the background). It was observed that in Digita, even the poor lighting conditions, this does not preclude its application. In more severe conditions, you can use common or flashing lights directed to try to create a diffuse light without shadow.

In traditional photogrammetry systems, rapidly acquires a large amount of data that must be stored in a large digital computer. It was observed that, in type, the dimensional data files generated and stored is much smaller and has no trouble being stored in an ordinary PC.

Photogrammetric systems use a relatively new technology, requiring expertise in computers and electronics to keep them and adapt them to specific applications. While Digita System requires no special expertise in the use of their tools. The only requirement is about the knowledge of anthropometric landmarks.

Analyzing the statistical results related to research, observe, with respect to the ethnicity of the population studied, a possible self-assessment of individuals who can instill some bias, however, each person was asked to mention which multiethnic which appeared on his birth certificate

Another factor to note was the large concentration of subjects contained within the age range from 18 to 24 years, which could only be proven by analysis of the data, with the completion of the lift.

With the presentation and statistical analysis, one could observe the immense diversity of body segments dimensional individuals. Citing, for example, frequency analysis and cumulative gross of variable height, could be seen that the dimensions found for this variable have an extremely low rate of recurrence, and found one to four identical values.

However, the study made it possible to tabulate the data in order to present data broken down between

sex, age, ethnicity, always presenting the percentiles 2.5, 97.5 and 50 coming up also to expose the percentiles 5 and 95 in some analysis.

Through the detailed analysis of these could be felt even more frequent anthropometric variables in surveys of this type. When comparing the variables studied with the surveys published by Panero and Zelnik (2008) [7] and the National Research Institute - INT (1988), we observed concomitant four body segments: height, eye height, shoulder height and popliteal height, and the first that offers the most complete dimensional data.

6. Conclusions

With the end of the study, evaluating the results, we could see the real efficiency of the software type, in a short amount of time, it was possible to survey data numerically equivalent to several international surveys.

The validation of Digita tools by a study code, and spread the technique, he broke a "taboo", noting the fact that, with this tool, you can perform to a large scale anthropometric survey in Brazil.

We emphasize the usefulness of Digita System as a low-cost tool for obtaining anthropometric data and relevance of their application for obtaining data representative of the population. With the low cost, you can train staff in various regions of the country and filling the anthropometric data of our population.

Thus, after the verification and validation of Digita System, the main recommendation lies in its use for a survey with a larger sample population, which can be used in many Brazilian cities and culminating in a statistically representative sample of the population of the country.

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