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# Photogrammetry procedures applied to anthropometry

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**Abstract.** This study aims to evaluate the reliability and establish procedures for the use of digital photogrammetry in anthropometric measurements of the human hand. The methodology included the construction of a platform to allow the placement of the hand always equivalent to a distance of the camera lens and to annul the effects of parallax. We developed a software to perform the measurements from the images and built up a subject of proof in a cast from a negative mold, this object was subjected to measurements with digital photogrammetry using the data collection platform in caliper and the Coordinate Measuring Machine (MMC). The results of the application of photogrammetry in the data collection segment hand, allow us to conclude that photogrammetry is an effective presenting precision coefficient below 0.940. Within normal and acceptable values, given the magnitude of the data used in anthropometry. It was concluded photogrammetry then be reliable, accurate and efficient for carrying out anthropometric surveys of population, and presents less difficulty to collect in-place

Keywords: Anthropometry, Digital Photogrammetry, photogrammetry

## 1. Introduction

This study aims to evaluate the accuracy of data obtained from digital photogrammetry and their use in anthropometric data. Peebles and Norris (2000) conclude that the collection of anthropometric data should be conducted in order segment, recommending that each variable should be to determine the best sampling technique.

Petroski (1999) points out that to perform anthropometric measurements should follow a international methodology set, so that the published results are clearly understood and can be used by other authors. And considering the need to develop simple and effective techniques for catching body size, we attempted to apply the technique of photogrammetry to collect data from the human hand, with the goal of developing a descriptive study of this technique so that it can be replicated to large population samples.

For the collection of anthropometric body parts is recommended adjustments in the camera placement and object so as to cancel errors of scale, in agreement with Meunier and Yin (2000). Roebuck (1993) asserts that the improper placement of the camera makes the collection vulnerable to errors of parallax, which can be corrected by placing a measurement reference and scale in the same plane as the object that is being photographed. Mullin and Taylor (2002) reported that morphological data collected through the images are very common. This method involves digital image capture and analysis in software developed for this purpose, using as reference marks located and identified during the examination of the images.

Barroso et al (2005), conducted research with 891 people using anthropometry for that digital camera of 2 (two) megapixel, and to calibrate the image installed on the same plane of a voluntary stand with brands that served as a scale.

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## 2. Methods

The method for capturing images included the construction of a platform, as Figure 1, to allow the placement of the hand always equivalent to a distance from the camera lens, aiming to reduce the effects of parallax in performing the measurement on the image Picture. Once the photographic image of the body segment, we go to the next stage, which is the measurement software. Software was developed specifically for this purpose.

It was built a test object in plaster representative of a human hand, figure 2. The aim of this step was to evaluate different measuring instruments in the "object test" to check their reliability.


Figure 1- Plataform for position of the hand

Figure 2- Test object

The instruments used were: digital photogrammetry using the platform for data collection, and digital caliper (Mitutoyo) with MMC (coordinate measuring machine) the latter on account of their precision and reliability was considered the gold standard reference.

The Coordinate Measuring Machine (CMM) is presented in Figure 3. The CMM is applied in the engineering industry, using the programming CNC (Computer Numerically Controled). It is based on the principle of recognition of points in space (x, y, z), and algorithmically transformed relations between the coordinated in precise measurements. In this study we use the model Discovery II D8 for taking measurements of the object of proof (Test object). This equipment uses the CAD software PCDMIS + +. It features resolution of 0.010 mm; accuracy with error of5, 0 +1.0 L/200 micron probing error of 5 mm.

Figure 3. Coordinate Measuring Machine (CMM)

The test object was measured on 29 variables (widths of the palm, proximal 2nd finger, distal of the 2nd finger, proximal 3rd finger, distal 3rd finger, proximal of the 4th finger, distal to the 4th finger, proximal of the 5th finger distal of the 5th finger,

hand length, full of 1st finger, proximal 1st finger, distal to the 1st finger, all of 2nd finger, the proximal 2nd finger, middle of the 2nd finger, distal of the 2nd toe, total 3rd finger, proximal 3rd finger, middle of the 3rd finger, distal 3rd finger, total 4 th finger, proximal 4th finger, middle of the 4th finger, distal 4th finger full of the 5th finger, proximal of the 5th finger, middle of the 5th finger distal the 5th finger). The figure 3 shows the proximal, distal and total lengths that was used in this study. To evaluate the use of platform and software for measurement, 50 measurements were performed with each instrument measured (caliper and digital photogrammetry).

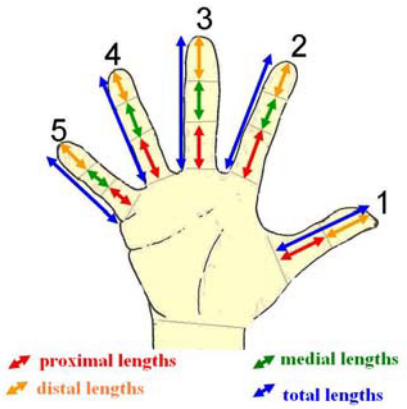


Figure 3- Illustration of measurements of finger length (adapted from Peebles and Noris, 2000)

## 3. Results

To validate the method of data by photogrammetry anthropometric aspects were observed with respect to its precision and accuracy in its reproducibility.

Table 1 presents the results of measuring the test object subjected to the three instruments, they were, MMC - "gold standard" measurement software with photogrammetry and digital caliper.

In photogrammetry and digital caliper data presented are for the averages of the measurements. In the case of photogrammetry 200 measurements were performed to try to eliminate a possible variability of skill of the researcher, with the technique, ignoring the 150 first measurements.

The data presented represent the average of 50 measurements and refer to the same object as proof of the figure 2. From the collections made by photogrammetry and digital caliper, the data were compared with a measure called "gold." It was considered "as gold" as performed by the CMM. The measure "gold" was accepted as true and invariant metric given its precision and the index of reliability and accuracy of the CMM.

The data showed that photogrammetry is effective with a coefficient of accuracy below .940 in just one variable, this inaccuracy is equivalent to 2.71 mm, other data showed values of difference of 0.8 mm, this efficiency was measured when comparing the photogrammetry data with data obtained using the MMC, as shown in Table 1.

The coefficient of variation of 50 measurements of each of the 29 variables is presented in table 2. We can conclude from these results that for all variables, the method of collection with the use of photogrammetry is highly accurate. The lowest rate of accuracy was found to be 0,897 mm in length distal of the 4th finger. Even this lower value has a high accuracy with this, we can conclude that the instrument has high precision metric to anthropometric measurement.

In addition to accuracy, the instrument must also present results that approximate the true measure, "gold standard" for this calculation was carried out of the range proposed for each of the above measures, and calculated the percentage of each variable approach . Five measurements were performed in order to reduce uncertainty about the extent gold and were compared with respect to their percentage of errors, table 3.

When compared with data from the MMC caliper he had even less exact, but within normal and acceptable values, given the magnitude of the data used in anthropometry. It was concluded to be the photogrammetry reliable, accurate and efficient for carrying out anthropometric surveys of population, and presents fewer difficulties for the collection in place.

Table 1
*Results of measurements of the proof object*

| | Description of the variables | MMC [1] | Photogrammetry [2] | Digital Caliper[3] |
|---|---|---|---|---|
| | | | Average (standard deviation) | |
| 1 | Width palm | 97,250 | 95,510 (± 0,11) | 95,446 (± 0,38) |
| 2 | Proximal width of the 2nd finger | 23,070 | 20,550 (± 0,13) | 22,750 (± 0,14) |
| 3 | Distal width of the 2nd finger | 19,810 | 17,456 (± 0,10) | 19,482 (± 0,04) |
| 4 | Proximal width of the 3rd finger | 23,460 | 22,080 (± 0,13) | 23,392 (± 0,08) |
| 5 | Distal width of the 3rd finger | 19,730 | 18,156 (± 0,11) | 19,562 (± 0,21) |
| 6 | Proximal width of the 4th finger | 22,290 | 21,152 (± 0,11) | 21,982 (± 0,16) |
| 7 | Distal width of the 4th finger | 18,640 | 18,070 (± 0,11) | 18,606 (± 0,07) |
| 8 | Proximal width of the 5th finger | 18,980 | 17,408 (± 0,11) | 18,416 (± 0,11) |
| 9 | Distal width of the 5th finger | 17,500 | 16,286 (± 0,11) | 17,232 (± 0,14) |
| 10 | Total length of the hand | 189,420 | 186,900 (± 0,14) | 188,490 (± 0,91) |
| 11 | Total length of the 1st finger | 65,280 | 63,238 (± 0,12) | 65,650 (± 1,47) |
| 12 | Proximal length of the 1st finger | 30,070 | 30,588 (± 0,13) | 30,868 (± 0,57) |
| 13 | Length of a distal finger | 35,800 | 32,864 (± 0,10) | 35,822 (± 1,10) |
| 14 | Total length of the 2nd finger | 73,500 | 73,714 (± 0,12) | 73,110 (± 1,21) |
| 15 | Proximal length of the 2nd finger | 25,640 | 26,294 (± 0,12) | 25,840 (± 0,41) |
| 16 | Medial length of the 2nd finger | 22,330 | 22,258 (± 0,10) | 22,466 (± 1,04) |
| 17 | Distal length of the 2nd finger | 25,620 | 25,292 (± 0,09) | 25,506 (± 0,59) |
| 18 | Total length of the 3rd finger | 80,850 | 79,424 (± 0,40) | 80,198 (± 0,91) |
| 19 | Proximal length of the 3rd finger | 28,160 | 27,360 (± 0,12) | 27,776 (± 0,66) |
| 20 | Medial lenght of the 3rd finger | 26,060 | 27,650 (± 0,11) | 26,338 (± 0,48) |
| 21 | Distal lenght of the 3rd finger | 26,620 | 26,056 (± 0,09) | 25,936 (± 0,84) |
| 22 | Total length of the 4 th finger | 76,850 | 76,682 (± 0,09) | 76,120 (± 0,60) |
| 23 | Proximal length of the 4 th finger | 23,520 | 23,406 (± 0,11) | 23,848 (± 0,36) |
| 24 | Medial lenght of the 4 th finger | 25,740 | 26,306 (± 0,10) | 25,976 (± 0,29) |
| 25 | Distal lenght of the 4 th finger | 27,610 | 26,924 (± 0,28) | 27,518 (± 1,85) |
| 26 | Total length of the 5th finger | 65,310 | 63,774 (± 0,32) | 64,110 (± 0,58) |
| 27 | Proximal length of the 5th finger | 21,720 | 21,800 (± 0,12) | 22,750 (± 0,39) |
| 28 | Medial lenght of the 5th finger | 18,460 | 18,106 (± 0,11) | 18,022 (± 0,33) |
| 29 | Distal lenght of the 5th finger | 25,150 | 24,186 (± 0,09) | 24,064 (± 0,36) |

[1].MMC; [2]2. photogrammetry measurement performed by photo and measured using software; [3]3. caliper measurement.
* Information in millimeters (mm)

Table 2

*Coefficient of variation of the data by photogrammetry*

| | | **Coefficient of variation.** |
|---|---|---|
| 1 | Width palm | 0,987 |
| 2 | Proximal width of the 2nd finger | 0,938 |
| 3 | Distal width of the 2nd finger | 0,941 |
| 4 | Proximal width of the 3rd finger | 0,941 |
| 5 | Distal width of the 3rd finger | 0,940 |
| 6 | Proximal width of the 4th finger | 0,947 |
| 7 | Distal width of the 4th finger | 0,938 |
| 8 | Proximal width of the 5th finger | 0,936 |
| 9 | Distal width of the 5th finger | 0,937 |
| 10 | Total length of the hand | 0,992 |
| 11 | Total length of the 1st finger | 0,980 |
| 12 | Proximal length of the 1st finger | 0,958 |
| 13 | Length of a distal finger | 0,970 |
| 14 | Total length of the 2nd finger | 0,983 |
| 15 | Proximal length of the 2nd finger | 0,952 |
| 16 | Medial length of the 2nd finger | 0,955 |
| 17 | Distal length of the 2nd finger | 0,965 |
| 18 | Total length of the 3rd finger | 0,950 |
| 19 | Proximal length of the 3rd finger | 0,956 |
| 20 | Medial lenght of the 3rd finger | 0,958 |
| 21 | Distal lenght of the 3rd finger | 0,964 |
| 22 | Total length of the 4 th finger | 0,988 |
| 23 | Proximal length of the 4 th finger | 0,955 |
| 24 | Medial lenght of the 4 th finger | 0,963 |
| 25 | Distal lenght of the 4 th finger | 0,897 |
| 26 | Total length of the 5th finger | 0,950 |
| 27 | Proximal length of the 5th finger | 0,943 |
| 28 | Medial lenght of the 5th finger | 0,941 |
| 29 | Distal lenght of the 5th finger | 0,962 |
| | Average | 0,954 |

Table 3

*Descriptive results:* Mean Square Error and Mean Absolute Error

| | | Photogrammetry | Digital Caliper | Photogrammetry | | Digital Caliper | |
|---|---|---|---|---|---|---|---|
| | | Mean Square Error | | Mean Absolute Error | | | |
| 1 | Width palm | 5,29 | 3,38 | 1,90 | 2% | 1,80 | 2% |
| 2 | Proximal width of the 2nd finger | 8,35 | 0,12 | 2,61 | 11% | 0,31 | 1% |
| 3 | Distal width of the 2nd finger | 6,76 | 0,10 | 2,35 | 12% | 0,32 | 2% |
| 4 | Proximal width of the 3rd finger | 5,13 | 0,01 | 1,82 | 8% | 0,08 | 0% |
| 5 | Distal width of the 3rd finger | 4,10 | 0,06 | 1,74 | 9% | 0,22 | 1% |
| 6 | Proximal width of the 4th finger | 3,30 | 0,12 | 1,51 | 7% | 0,30 | 1% |
| 7 | Distal width of the 4th finger | 2,10 | 0,01 | 1,17 | 6% | 0,07 | 0% |
| 8 | Proximal width of the 5th finger | 3,78 | 0,32 | 1,67 | 9% | 0,56 | 3% |
| 9 | Distal width of the 5th finger | 2,64 | 0,09 | 1,40 | 8% | 0,27 | 2% |
| 10 | Total length of the hand | 9,94 | 1,65 | 2,53 | 1% | 0,94 | 0% |
| 11 | Total length of the 1st finger | 7,17 | 2,24 | 2,21 | 3% | 1,30 | 2% |
| 12 | Proximal length of the 1st finger | 2,93 | 0,94 | 1,35 | 4% | 0,80 | 3% |
| 13 | Length of a distal finger | 9,77 | 1,18 | 2,94 | 8% | 0,86 | 2% |
| 14 | Total length of the 2nd finger | 2,47 | 1,57 | 1,27 | 2% | 0,91 | 1% |
| 15 | Proximal length of the 2nd finger | 2,27 | 0,20 | 1,16 | 5% | 0,36 | 1% |
| 16 | Medial length of the 2nd finger | 0,77 | 1,07 | 0,71 | 3% | 0,60 | 3% |
| 17 | Distal length of the 2nd finger | 1,10 | 0,35 | 0,89 | 3% | 0,46 | 2% |
| 18 | Total length of the 3rd finger | 6,14 | 1,23 | 1,92 | 2% | 0,78 | 1% |
| 19 | Proximal length of the 3rd finger | 2,51 | 0,58 | 1,25 | 4% | 0,66 | 2% |
| 20 | Medial lenght of the 3rd finger | 3,44 | 0,30 | 1,66 | 6% | 0,40 | 2% |
| 21 | Distal lenght of the 3rd finger | 1,39 | 1,15 | 0,96 | 4% | 0,93 | 3% |
| 22 | Total length of the 4 th finger | 1,34 | 0,88 | 0,94 | 1% | 0,73 | 1% |
| 23 | Proximal length of the 4 th finger | 1,53 | 0,22 | 0,98 | 4% | 0,32 | 1% |
| 24 | Medial lenght of the 4 th finger | 1,61 | 0,14 | 1,01 | 4% | 0,33 | 1% |
| 25 | Distal lenght of the 4 th finger | 1,21 | 3,37 | 0,92 | 3% | 1,63 | 6% |
| 26 | Total length of the 5th finger | 4,54 | 1,76 | 1,85 | 3% | 1,20 | 2% |
| 27 | Proximal length of the 5th finger | 1,94 | 1,22 | 1,11 | 5% | 1,03 | 5% |
| 28 | Medial lenght of the 5th finger | 1,31 | 0,29 | 0,85 | 5% | 0,47 | 3% |
| 29 | Distal lenght of the 5th finger | 1,79 | 1,30 | 1,06 | 4% | 1,09 | 4% |

* Information in millimeters (mm)

The average time of measurement using the caliper to perform the data's collection from 29 variables in the test object was 12 minutes. To perform the same measurement with calipers on a voluntary measurement time was over 15 minutes.

The average time measurement of the object's images in the software was 6 minutes. There is no change in position of the segment measured (hand). But the problems were evidenced by the photogrammetric images in the real situations, arising from reflection on the image at the capture time or when the individual was photographed and he/she was not positioned in the right position.

The location of reference points for the collection of data is a point of extreme importance to define the variable. In this study points that showed a greater degree of difficulty, regardless of technique (digital caliper or photogrammetry), were on the fingertips, where there is the determination of the point of greatest distance, and at the midpoint of the skin folds.

The variability of the photogrammetry data's depends on the collection method and the quality of the cameras and equipment. For the use in the real situation with subjects it is necessary ensures that all individuals in the sample will be measured on equal terms, especially in aspects of distance and alignment with the camera.

## 4. Discussion

The variability in anthropometric measurement is greater in caliper measurement caused by variations in the technique, is responsible for the higher incidence of error. The values found in the measurement with MMC, compared with values obtained in measuring with photogrammetry, proved too accurate, i.e. the measured values presented small variability. Among those who were less accurate are the distal length of the 4th finger, powered by the difficulty in locating the center of the joint and the tip of the finger, this problem was not so evident in other variables measured at similar conditions.The main problems reported in this study relate primarily to the procedures for data collection. Thus we observed the importance of using anti-reflective glass on the platform in order to reduce problems of glare in the picture. The use of the platform as part of positioning of the segment to be measured (in this case the object of proof, rigid body) showed a low variation in results between the 50 measurements taken for the same variable. This procedure aimed to evaluate the procedures to probe its use with subjects. So we feel that this study contributes to the development of procedures for the continuing study of digital photogrammetry applied anthropometry. We believe that digital photogrammetry can be applied mainly to obtain a larger number of variables compared to the digital caliper.

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