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Analysis of angular reading distortions of photographic images

Análise das distorções em leituras angulares de imagens fotográficas

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Abstract

Background: Although photogrammetry is a widespread technique in the health field, despite of the methodological efforts distortions in the angular readings of the images are common. **Objective:** To measure the error of angular measurements in photo images with different digital resolutions in an object with pre-determined angles. **Method:** We used a rubber ball with 52 cm in circumference. The object was previously marked with angles of 10°, 30°, 60° and 90° degrees. The photographic records were performed with the focal axis of the camera perpendicular and three meters away from the object, without the use of optical zoom and a resolution of 3, 5 and 10 Megapixels (Mp). All photographic records were stored and a previously trained experimenter using the computer program *ImageJ* analyzed the angular values of each photo. The measurements were performed twice within a fifteen-days interval. Subsequently, we calculated the accuracy, relative error and error in degrees values, precision and the Intraclass Correlation Coefficient (ICC). **Results:** When analyzing the angle of 10°, the average accuracy of measurements was higher for those records of 3 Mp resolution compared to 5 and 10 Mp resolutions. The ICC was considered excellent for all resolutions. With regards to the analyzed angles in photographic records, it was possible to verify that the 90-degree angle photographs were more accurate, had lower relative error and error in degrees, and were more precise, regardless of image resolution. **Conclusion:** The photographs records that were taken with a 3 Mp resolution provided great accuracy and precision measurements and lower errors values, suggesting to be the proper resolution to generate image of angles of 10° and 30°.

Keywords: photogrammetry; image processing computer-assisted; instrumentation; validation studies.

Resumo

Contextualização: A biofotogrametria é uma técnica difundida na área da saúde e, apesar dos cuidados metodológicos, há distorções nas leituras angulares das imagens fotográficas. **Objetivo:** Mensurar o erro das medidas angulares em imagens fotográficas com diferentes resoluções digitais em um objeto com ângulos pré-demarcados. **Método:** Utilizou-se uma esfera de borracha com 52 cm de circunferência. O objeto foi previamente demarcado com ângulos de 10°, 30°, 60° e 90°, e os registros fotográficos foram realizados com o eixo focal da câmera a três metros de distância e perpendicular ao objeto, sem utilização de *zoom* óptico e com resolução de 3, 5 e 10 Megapixels (Mp). Todos os registros fotográficos foram armazenados, e os valores angulares foram analisados por um experimentador previamente treinado, utilizando o pro grama *ImageJ*. As aferições das medidas foram realizadas duas vezes, com intervalo de 15 dias entre elas. Posteriormente, foram calculados os valores de acurácia, erro relativo e em graus, precisão e Coeficiente de Correlação Intraclasse (ICC). **Resultados:** Quando analisado o ângulo de 10°, a média da acurácia das medidas foi maior para os registros com resolução de 3 Mp em relação às resoluções de 5 e 10 Mp. O ICC foi considerado excelente para as três resoluções de imagem analisadas e, em relação aos ângulos analisados nos registros fotográficos, pôde-se verificar maior acurácia, menor erro relativo e em graus e maior precisão para o ângulo de 90°, independentemente da resolução da imagem. **Conclusão:** Os registros fotográficos realizados com a resolução de 3 Mp proporcionaram medidas de maiores valores de acurácia e precisão e menores valores de erro, sugerindo ser a resolução mais adequada para gerar imagem de ângulos de 10° e 30°.

Palavras-chave: fotogrametria; análise de imagem assistida por computador; instrumentação; estudos de validação.

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Introduction

To evaluate the alignment of body segments many methods have been used, such as visual analysis[1], radiographs[2], video cameras[3-6], goniometry[7-11] and photogrammetry[12-17]. The use of biophotogrammetry has been recommended for postural evaluation due to the relative simplicity of the technique, low cost and for being able to quantify postural alterations which are difficult to measure by inspection[18,19].

Photogrammetry is a tool used as a support during the physical examination to quantify postural changes[12-17], changes in static balance[20,21] and analysis of respiratory mechanics[22,23]. With methodological improvements, this technique was rapidly spread and several health professionals nowadays have been using this technique to quantify of the changes in the visible external body structures[24].

The intra and inter-rater reliability, which was evaluated by the quantification of the asymmetries and postural deviations angles of the face and body in standing position in the frontal, sagittal and posterior planes, presented correlation levels varying from good to excellent for most of the assessed angles[15,25], following the classification criteria of Wahlund, List and Dworkin[26]. However, the method has low sensibility when the photographic records are performed in the posterior plane[19]. Van Niekerk et al.[27] analyzed through the biophotogrammetry the sitting position of adolescents and compared these images to those observed by low-dose X-ray records. The authors suggest the indication of biophotography as a gold standard, since no statistical differences in the postural analysis was found[16].

Although few studies have carefully described the parameters used in the process of image acquisition, several methodological efforts and standards are described in the literature to avoid distortion in the angular readings. For example, the environment must be appropriately iluminated[17], the camera used must be positioned at the same distance for all volunteers; the use of the tripod to maintain focus and the framing are important for an appropriate record[18,28]. Moreover, the optical center of the camera must be perpendicular to the plane of the postural angle of interest, as it may minimize the perspective error caused by the refraction of the lens characteristics[29].

The current market offers several options of cameras and image resolutions. Therefore, it is essential to know which model is the most appropriate for a high-quality evaluation. Machado, Souki and Mazzieiro[30] analyzed the influence of the digital camera resolution on the photographic record through the visual evaluation of definition and clarity of only one facial digital image in the sagittal plane with different resolutions (ranging from 1 to 7 Mp). The results showed that there were no significant differences among the used resolutions, regardless of the visualization method used. However, no studies that verified error measures, accuracy and reproducibility in relation to the resolution of the images were found.

For an instrument to be reliable and have acceptable levels of reproducibility, sensibility and intra and inter-rater reliability, other aspects should be taken into consideration, such as accuracy and precision of the measurements. Accuracy of a measurement system is the nearness degree or reliability with which the instrument measures the real value of the measure that have been measured. On the other hand, precision assesses the proximity between the values obtained by repeating the measurement process. Thus, the greater the accuracy of the measurement process, the closer is the result of the measurement of the true value, while the precision concerns the measurements reproducibility, being the greater the precision, the lower the variability between the measurements[31,32].

Therefore, the objective of this study was to verify the error of angular measurements due to different resolutions of photographic digital images.

Method

Angles in the XYZ planes were marked on a rubber ball with a circumference of 52 cm (Figure 1). The object was placed on a fixed and stable surface with one meter high and in front of a non-reflective screen. Four angles were marked on the ball, 10º, 30º, 60º e 90º, being two fixed points and only one variable point in order to obtain these angles. All angles were demarcated by the Precision Oficina at the Universidade de São Paulo (USP) in Ribeirão Preto, Brazil.

The photographic records were performed with the digital photographic camera Sony® DSC T700, with maximum

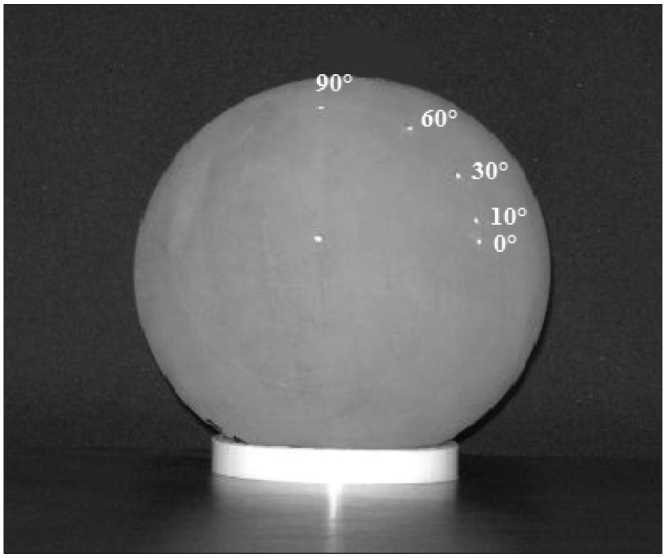

Figure 1. Rubber Ball marked with angles of 10º, 30º, 60º and 90º degree used for the photographic records.

resolution of 10.1 Megapixels (Mp), Carl Zeiss Vario-Tessar® lens. The camera was fixed firmly on a Manfroto® tripod, with a Manfroto® head adjusted to a meter of height even with the horizontal plane and the optical center was adjusted to the center of the ball.

In the procedure of data acquisition, the rubber ball was photographed with the camera's focal axis perpendicular and three meters away from the camera, without the use of optical zoom and flash, with resolution of 3, 5 and 10 Mp. A direct artificial lighting on the photographed plane of the ball was used to avoid the development of shadows.

All photographic records were stored in jpeg format, and the angular values were analyzed by a previously trained examiner, using the ImageJ program[33] on a monitor of trademark Acer®, LCD screen with 14.1 inches and resolution 1280x800 pixels. The measurements were performed on a random sequence for the angles and with an interval of 15-days between the analyses that were denominated, respectively, measurements 1 and 2. The ImageJ program, available on-line free[33], is a mathematical algorithm that transforms images points in Cartesian coordinate axes, allowing therefore the quantification of angles from the captured images.

Data analysis

The assessments of the measurement error was calculated from the precision values (random error), accuracy (systematic error), error in degrees, relative error and Intraclass Correlation Coefficient (ICC), using the mean values of measurements 1 and 2 calculated using the Microsoft Office Excel 2007 for the operating system Windows.

The precision of the measurements was estimated by calculating the standard deviation of the measurements 1 and 2 divided by the square root of the mean of measurements 1 and 2. The precision value ranges between zero and one, being zero the highest precision and one the lowest precision.

The equation used to calculate the percentage of accuracy is described below:

$$\% \text{ Accuracy} = 100 - \frac{(\text{Real value} - \text{Measured value})}{\text{Real value}}$$

The absolute error of the measurements was calculated by subtracting the real angle value from the measured value in the photo took by the computer program. The relative error was obtained by calculating the ratio between the absolute error and the true value of the measure. The accuracy values and relative error range from 0 to 100%, being 100% the value of the greatest accuracy and the highest relative error.

The ICC was calculated using the *Instat prism 5*® program for each image resolution (3, 5 and 10 Mp). Four values of the measurement 1 and four values of the measurement 2 were considered for each image resolution. According to Fleiss, Levin and Paink[34], the reproducibility is considered excellent above 0.85.

Results

The comparison between the resolutions of cameras and the angular measurements showed similar accuracy values between the measurements 1 and 2 in all used resolutions (Table 1). However, when we compared the accuracy mean of the photographic

Table 1. Mean values from first (1) and second (2) measurements of angles in the digital photography pictures, mean accuracy (%), mean relative error and error in degrees, precision of measurements and intraclass correlation coefficient.

Camera Resolution	Pre-Determined Angle	Measure 1	Measure 2	Accuracy (%)	Error (degrees)	Relative Error (%)	Precision	ICC
3 Mp	10°	9.725	10.176	97.745	0.226	2.255	0.101	0.98
	30°	26.85	26.565	89.025	3.293	10.975	0.039	
	60°	55.068	56.31	92.815	4.311	7.185	0.118	
	90°	91.603	91.432	98.314	1.518	1.686	0.013	
5 Mp	10°	7.967	8.584	82.755	1.725	17.245	0.152	0.99
	30°	28.072	27.072	91.907	2.428	8.093	0.135	
	60°	56.634	54.728	92.802	4.319	7.198	0.181	
	90°	90	91.102	99.388	0.551	0.612	0.082	
10 Mp	10°	9.593	8.932	92.625	0.738	7.375	0.154	0.99
	30°	28.74	27.617	93.928	1.822	6.072	0.15	
	60°	54.744	54.612	91.13	5.322	8.87	0.013	
	90°	90	90.841	99.533	0.42	0.467	0.063	

Mp=Megapixels.

records among the different resolutions, the 3 Mp is higher than the resolutions of 5 and 10 Mp for the smallest angle.

The mean relative error of the measures with a resolution of 5 Mp was higher compared to the photographic records of 3 and 10 Mp, which were similar to each other. However, the lowest accuracy and precision values of the measurements were observed in the photographic records of 5 Mp, followed by the 10 and 3 Mp.

Regarding the angles analyzed in the photographic records, a higher accuracy, lower relative error and lower error in degree, as well as, a greater precision for the angle of 90º could be observed, with no difference between the resolutions of the adopted images. However, for the angle of 10º, the best records were observed with the image resolution of 3 Mp.

In relation to the images with resolution of 10 Mp, the measures of 10º e 30º showed the lowest values of precision, while the angle of 60º had the highest error in degrees among the evaluated angles.

The ICC values showed excellent levels for the three analyzed resolutions.

Discussion

Considering that a measure should be accurate and precise, the results of this study indicate that the records of 3 Mp are the most appropriate to represent the pre-determined angles. Moreover, angles of 10º e 90º were best angles represented by the photogrammetry in relation to the 30º e 60º angles, as they reached a better accuracy and a greater precision in the records of 3 Mp.

The angle of 90º was the most accurate, independent of the quality of the photographic record probably due to the fact of this angle be perpendicular. When the ImageJ program to form the angle is used the line drawn between the two points is transformed into a continuous straight line when there is no inclination, suggesting the exact location of the second point. By analyzing the angles of 10º and 30º, obtained with high-resolution cameras, it becomes more difficult the adequately measure the angle observed in the digital photographic record with a higher number of points to represent the image. The higher the resolution of the used camera more points will be formed in the digital image, multiplying the possible points to be chosen to draw the angles, hampering therefore its acquisition.

In a previous study, Iunes et al.[15] suggested 22 angles acquired through photos of 2 Mp in the sagittal, frontal and posterior planes of the human body to evaluate the postural alignment of people without postural alterations. About 50% of the angles suggested by the authors for the evaluation of postural asymmetries had measures between 0º and 10º. Thus, it is necessary to consider that angles smaller than 10º may present reduction of precision and accuracy, when obtained from images with high-resolution cameras, such as 5 and 10 Mp.

The application of photogrammetry to record postural alignment has already been questioned. Döhnert and Tomasi[14] verified that the biophotogrammetry cannot be used as screening for detection of mild scoliosis (mean angle Cobb 5.5º), as it presents low sensibility and specificity. Iunes et al.[35] suggested that the data of postural alignment obtained by photogrammetry and by visual inspection should be considered independently, since the agreement between the evaluations was non-significant in most of the angles used in the analysis.

The data reveal the inexistence of a linear correlation between the use of a higher resolution of photographic image and significantly better results regarding the ICC, precision, accuracy, relative error and error in degrees. Therefore, as it had already been verified when comparing the increase in digital resolutions through visual analysis of definition and clarity, the results showed no significant differences.

The present study presents some limiting factors such as the clarity changes, limited by the definition of the monitor used for data analysis; and the non-controllable parameters of the camera, as the clarity index and the rate of lens deformation. It is important to note that the images were collected in a single day, with seconds of differences between them, and although it has been controlled the use of this instrument approaches the acquisition of the image generated in the clinical practice.

Conclusion

Based on data of the present study, it can be observed that the photographic record performed with a resolution of 3 Mp provided measures with higher accuracy and precision values and lower error values, suggesting being the most appropriate resolution to generate photographic image of angles of 10º e 30º.

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