# PROJECTED LIGHT SYSTEM FOR TRUNK SURFACE RECONSTRUCTION AND VOLUME MEASUREMENT DURING RESPIRATION

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**KEYWORDS:** Biomechanics, Power Crust, videogrammetry, volume, surface reconstruction.

**INTRODUCTION:** There is an increasing interest on developing non invasive and accurate methods to obtain torso shape and deformation during movement. Methods like inductance pletismography (Warren et al. 1989), magnetommetry (Verschakelen & Demedts 1995) and kinematical analysis (Ferrigno et al. 1994) have been proposed to access the pulmonary function based on trunk motion analysis. Measurements of body shape and dimensions are widely used on ergonomic and anthropometry designs fields (Allen et al. 2004) and to estimate body segment parameters for the analysis of human movement (Wicke et al. 2009). The aim of this work was to present a video-based method for trunk volumes measurement during the respiration by means of projected light and surface reconstruction.

**METHOD**: Our projected light system used four digital video cameras (JVC 9500). One pair of cameras registered the anterior trunk surface and one pair registered the posterior trunk surface (acquisition frequency of 30Hz). For each pair of cameras one multimedia projector was used to project a dense grid of circular markers on the body surface. The video stream was segmented by pre-processing techniques, morphological operators and detection algorithms to obtain 2d coordinates of the projected markers. The RGB image was converted to grayscale (8 bits) and by using thresholds the gray scale image was converted to binary format (1 bit). In the binary image, outer boundaries of objects were tracing that nonzero pixels belonged to an object and 0 pixels constituted the background. The 2D coordinates were obtained by the mean value of the outer boundary markers. The correspondence between markers on the different image projections was established by a labeling process. This process assigned the same identification (number and order) to a marker on the different image projections taking account it position and orientation in the image relative to four knowing markers. The 3d coordinates of the labeled markers were obtained by using the camera calibration parameters by means of a Direct Linear Transformation method (Abdel-Aziz & Karara 1971). After 3D reconstruction, the anterior and posterior trunk surfaces were represented by two unorganized clouds of points. The surface reconstruction tool Power Crust (Amenta et al. 2001) was used to order the cloud of points and enclose the trunk volume. The volume of the enclosed trunk was obtained from an algorithm based on the discrete form of the divergence theorem (DTA) (Alyassin et al. 1994). The surface reconstruction and volume calculation procedures were accomplished in the VTK (Visualization Tool Kit: www.vtk.org). The accuracy and the reproducibility were obtained by the comparison between plastic trunk model volume obtained by water displacement and the volume obtained by our projected light method. The volume measurement of the plastic trunk by our method was performed five times. The accuracy was defined as follows: $a^2=b^2+p^2$. Where $p^2$ was the variance of the experimental data and b was the bias given by the difference between the mean value (experimental measurement) and the real value (direct measurement). The method was also tested in one male subject. The participant was sitting down with the arms on a waist and he was encouraged to execute three maximal consecutive inhale and exhale cycles.

**RESULTS:** To demonstrate the performance of our projected light system, some reconstructed surfaces of the plastic trunk are show in Figure 1. The accuracy of the optical volume measured relative to the real value was 2.9% (SD 0.08 litters). This method also demonstrated capability for measure the trunk volume variation during breathing once was obtained a coherent signal with the respiratory cycle phases.

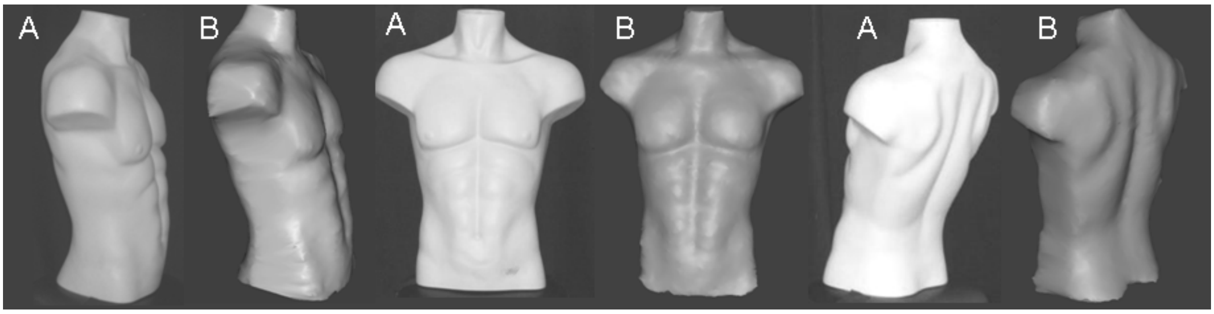


**Figure 1. Examples of the plastic trunk reconstructed by our optical method (B) in comparison with the original surface (A)**

**DISCUSSION:** Our method was capable to provide a trustworthy reconstructed trunk surface and measured trunk volume accurately and with high reproducibility. Better accuracy results for the volume measurement was only found in the literature by means of laser scan systems in static conditions (Wang et al. 2006). Another contribution of our proposed method is the segmentation and the labeling of a large number of projected markers in motion.

**CONCLUSION:** This novel development provides an important non-contact tool for the biomechanics field. It has potential application for the determination of body volumes to estimate body segment parameters.

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