PRINCIPLE OF BODY SCANNER MANESCAN®

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Abstract

This paper focuses on issues surrounding the scanning of the human body surface using the MaNescan® system. The basic philosophy consists of using a 2D method of active triangulation based on the cylindrical principle. The output is 3D data imported into a 3D programme called CATIA with an image of a standing or seated figure in digital form. In this 3D environment, the demonstration of manipulation of the complete object, its measurement and the evaluation of accuracy of the measured body dimensions is a non-contact method. It presents a strategy to measurements of the population without contact and to obtaining data for anthropometry. This enables to monitor the growing increase in the size of the human body and its subsequent variability. It can be applied to anthropology, to design clothes, linen and while considering the ergonomics of the design of machines and equipment.

Introduction

We can identify scanning of physical object surfaces in the technical and humanity disciplines. Any non-viable subject, but nowadays even human beings, can become the scanned objects.

Scanning of the human body surface, without the measuring instrument touching the surface of the body, differs from scanning of non-viable objects. This is especially so in the case of scanning technology that uses methods used for the provision of picture of the object. X-ray, ultrasound and also optic and holographic methods are ranked among the techniques used for non-viable objects.

The principle which MaNescan® is built on uses an active triangular method. ***Techniques of active triangulation*** consist of photographic reconstruction of the sensed object by spotlighting its surface using source of light and simultaneous sensing using a CCD sensor.

In active triangulation, a *ray of light (1D triangulation), light bar (2D triangulation) or structured light beam (3D triangulation)* are used to mark the surface.

The essence of active triangulation is to gain an image of the real world in 2D. This is done most often by a camera or a CCD camera. The image is transformed in a computer into existing programs or programs created for this purpose and to derive, from such an image, retroactively three-dimensional characteristics of the objects, i.e. conception of the shape and dimensions of the examined objects. Such a backward task offers multiple applications.

For scanning the human body surface at the Faculty of Textile of the Technical University in Liberec the system MaNescan® has been created. 2D active triangulation is used for solutions. Light bar for spotlighting the human body surface is formed by the laser of the 2nd class.

1 Experiments

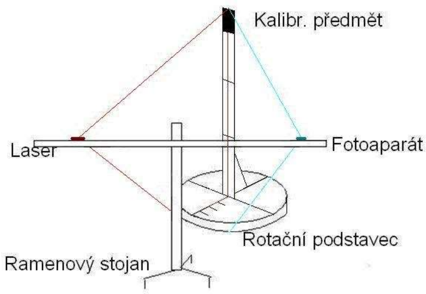
When working on my dissertation, I created a system designed for non-contact scanning of the human body surface under the name **MaNescan**. This was achieved with a special software **MiT_MaNescan**, for use as an aid specifically for education. MaNescan consists of rotating equipment controlled by a stepper motor, a shoulder stand, a calibration object and a seat for scanning sitting figures. See Figure 1.

a) b) c) d)

Source: Own based on [1]

Fig. 1: *Rotary stand with anatomic poles and controller with start button a), shoulder stand for placing a camera and lasers b), calibration object c), seat for scanning the sitting figures d)*

The whole system consisting of a rotating stand, sensor – camera, and laser (lasers), forms a triangular layout. The system must be stable and fixed. Any change in turning, shifting or by moving one of the components, even the adjustment of camera (objective) parameters, necessitates re-calibration of the whole system. A schematic layout of the workplace with calibration subjects is shown in Figure 2.



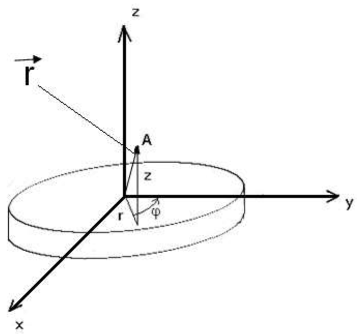
Source: Own based on [1]

Fig. 2: *Schematic layout of the workplace for scanning human body surface with a calibration subject*

The coordinates of the actual scan can be calculated from the relative position of the rotating stand, the laser and the sensor. With regard to the given task, the *cylindrical system of coordinates r, z,* φ was chosen.

When reconstructing the image, we work with the rotating stand. This is the reason why it is appropriate to express individual points of the measured object using cylindrical coordinates. See Picture 3. Point *A* constitutes one point of the scanned line. Vector **r** has three scalar components *x, y, z*. These components are the required coordinates of point *A*. The same principle of calculation is used for processing the points of all the scanned lines on a figure.

The method is utilized so that individual steps can be monitored both during acquisitions of scans and also while evaluating them. The accuracy of this method primarily depends on the calibration of the system.



Source: Own based on [1]

Fig. 3: *Euclidean and cylindrical system*

$$\varphi = arctg\frac{x}{y} \tag{1}$$

$$r = \left|\sqrt{x^2 + y^2}\right| \tag{2}$$

$$x = r.\sin\varphi \tag{3}$$

$$y = r.\cos\varphi \tag{4}$$

$$z = z \tag{5}$$

The principle of measurement consists of acquiring images of the calibration object while the figure is standing on the rotating stand. Individual scanned images create profile of the body surface cuts whereas each creates a view profile from a different angle. Images are captured every 9° while the rotating equipment makes a complete circle of 360 degrees. Thus, 8 pictures of calibration scans and 41 pictures of the object – figure form the basis of the image. An example of a picture of a scanned line is demonstrated in Figure 4. Scanning is carried out in a dark room and so the examined person remains anonymous.

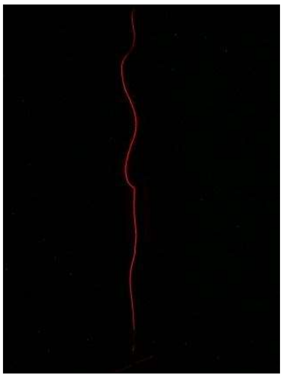


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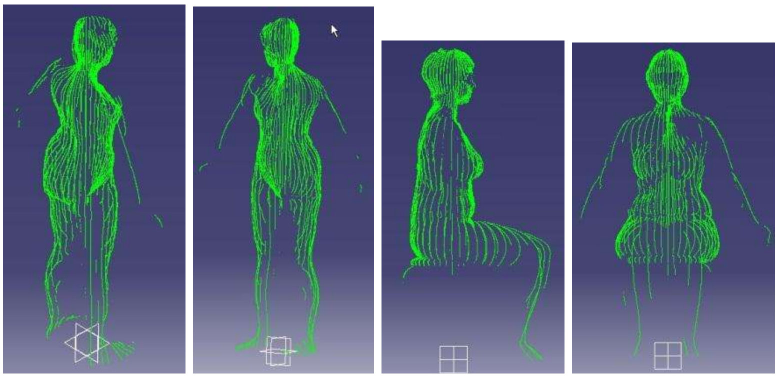
Fig. 4: *Example of an image of a scanned line on a figure*

Images are evaluated both semi-automatically and automatically. Semi-automatic evaluation uses the programs **Matlab** and **Excel.** The method and the principle used for processing by software **MiT_MaNescan** is elaborated. This program was used for automatic evaluation of scanned images of the somatic (body) examinations of young women.

The output of the above mentioned programs is a collection of points – of coordinates *x, y, z* – of which each scanned line consists. The import to the 3D CAD program, **CATIA,** allows imaging of the scanned standing or seated figures in 3D format and creates its so called "digital twin". See Figure 5.

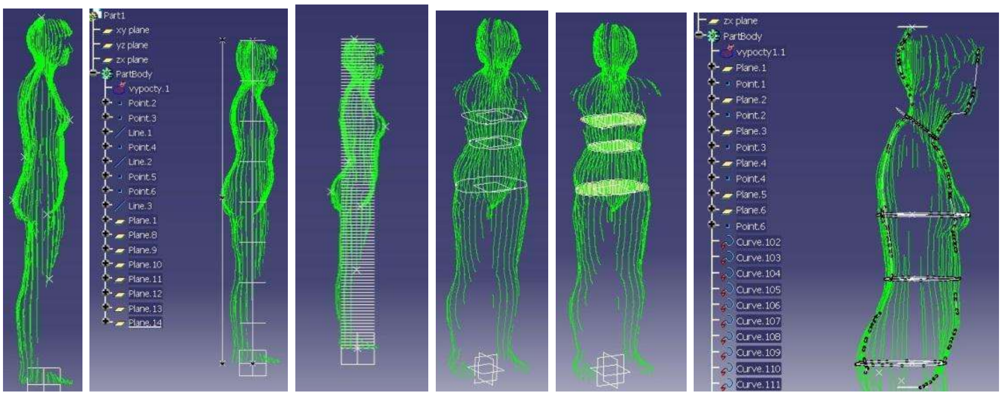


a) b) c) d)

Source: Own

Fig. 5: *Imaging of scanned standing figures a), b) and sitting figures c), d) in the 3D program CATIA*

In the 3D environment manipulation of the complete object and its scaling and evaluation can be performed. This means the figure can be turned and observed from various angles of vision. It can then be divided by horizontal, vertical levels, even bias, height, width, length, and girth dimensions can be measured. The procedure and measuring points are shown in Figures 6, 7, 8. Coverage of the figure surface with a solid layer is shown in Figure 9.



a) b) c) d) e) f)

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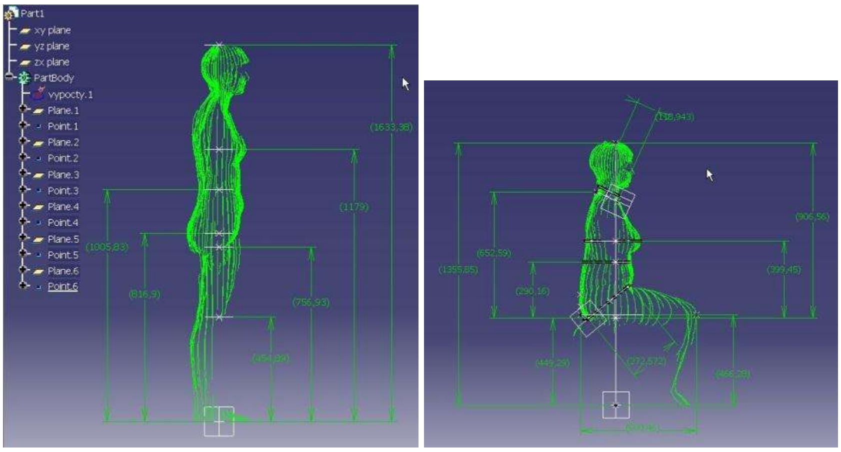
Fig. 6: *Imaging in the 3D program CATIA of: anthropometric points on figure a); levels b), c), horizontal cuts d), e), vertical cuts f)*



a) b)

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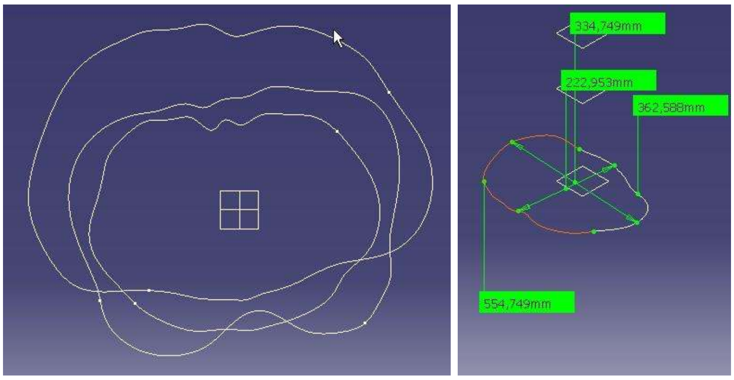
Fig. 7: *Measurement of heights in 3D program CATIA - standing figures a), sitting figures b)*



a) b)

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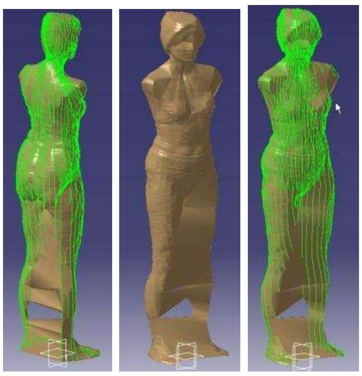
Fig. 8: *Imaging of horizontal cuts on body – section plans a) (chest, waist and hip girths) and their measuring b) in 3D program CATIA*



a) b) c)

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Fig. 9: *Coverage of the figure surface with a solid layer – rear view a), front view b) and c)*

Somatometric examination of a homogeneous set of 30 young women aged 18 to 30 years was carried out to verify the principle and accuracy of scanning using the MaNescan® system using the non-contact measurements. The examination was also conducted by a contact method. [1] Internationally defined points of common anthropometric measurements, accepted terminology and the methodology of body dimension measurements as stated in the ČSN standard were used for contact and non-contact measurements. [2]

For measuring, 17 dimensions, from which were chosen: ***six heights*** *(figure height Fh, breast height Bh, waist height Wh, crotch height Hh, knee height Kh) and* ***six widths*** *(frontal width of chest Fch, frontal width of waist Fwa, frontal width of hip Fhi, profile width of chest Pch, profile width of waist Pwa, profile width of hip Phi),* ***three girths*** *(chest girth Cg, waist girth Wg, hip girth Hg) and* ***two lengths*** *(back length Bl, pelvic arch length Ple).* [2]

The methodology of non-contact measurement in a 3D CAD program is similar to that of contact measurement with the only difference being that the procedure of measurement uses the figure in digital form. The measured object is stable in a 3D program. It can be revisited at any time, and re-measured and updated for other dimensions as requested. In order to determine accuracy, both methods, consisting of non-contact and contact, were compared. The differences in measurements were determined in centimetres and percentages and the basic statistical characteristics were evaluated.

The results of contact and non-contact methods and their average values in centimetres and percentage are shown in Figure10.

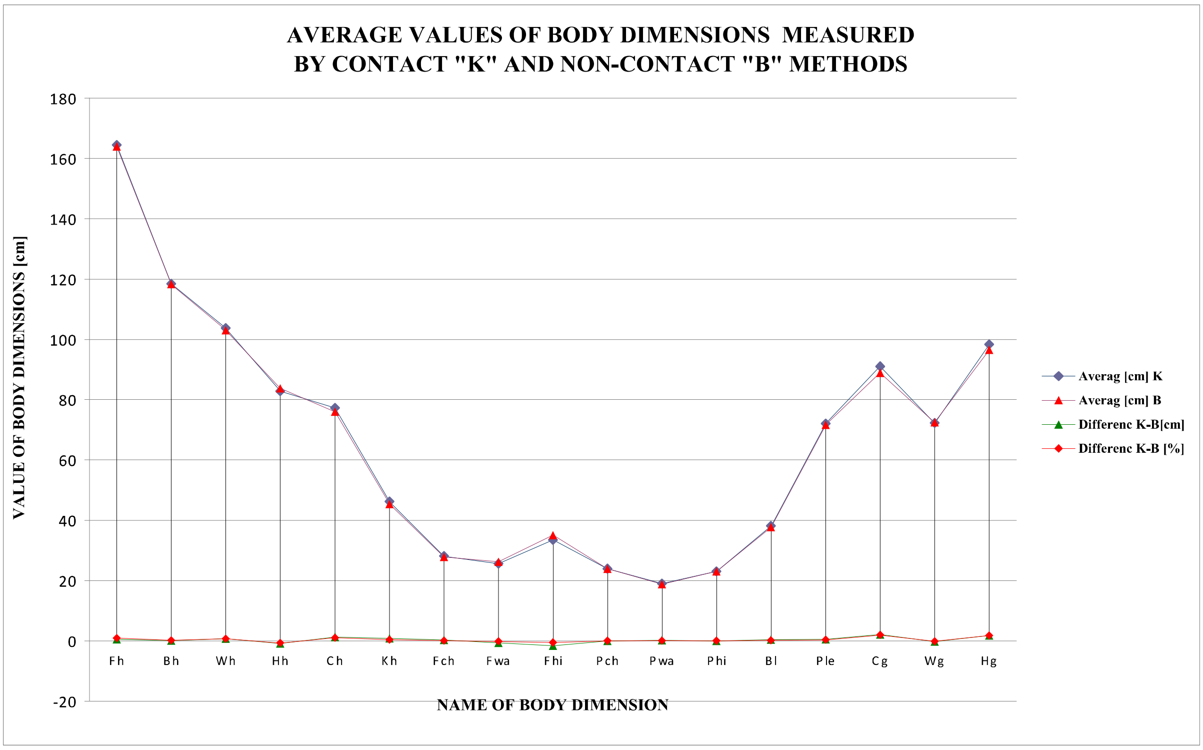

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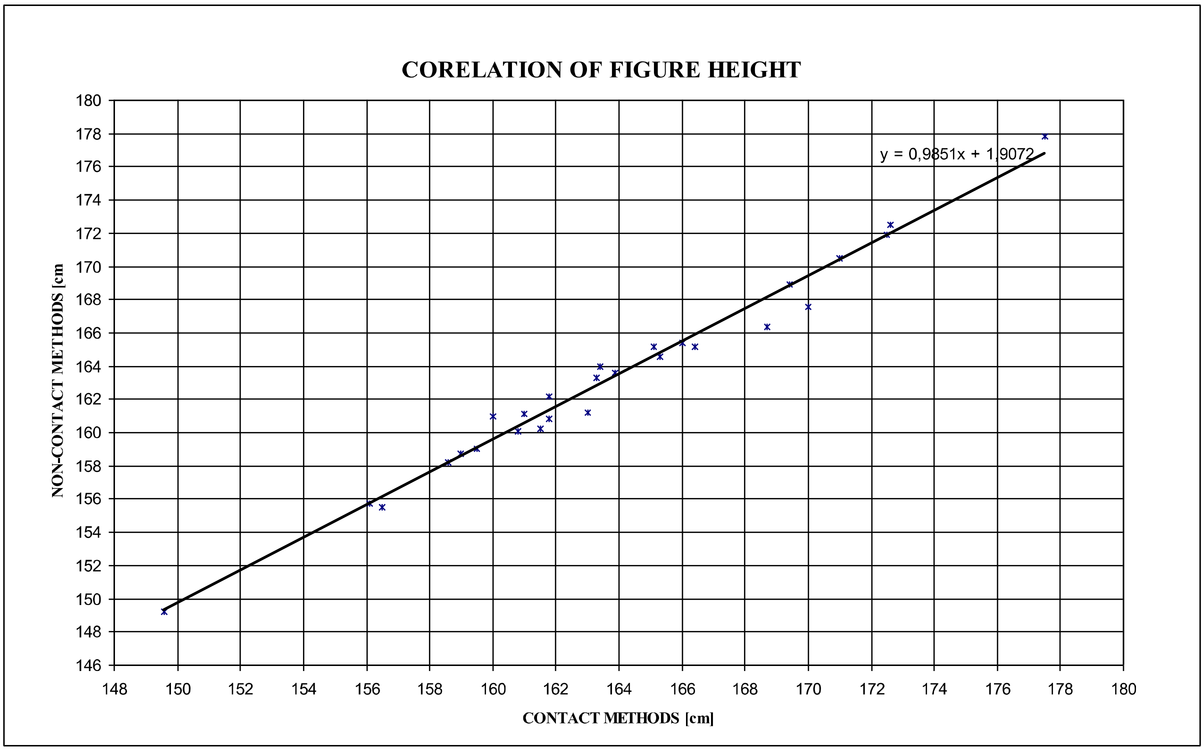
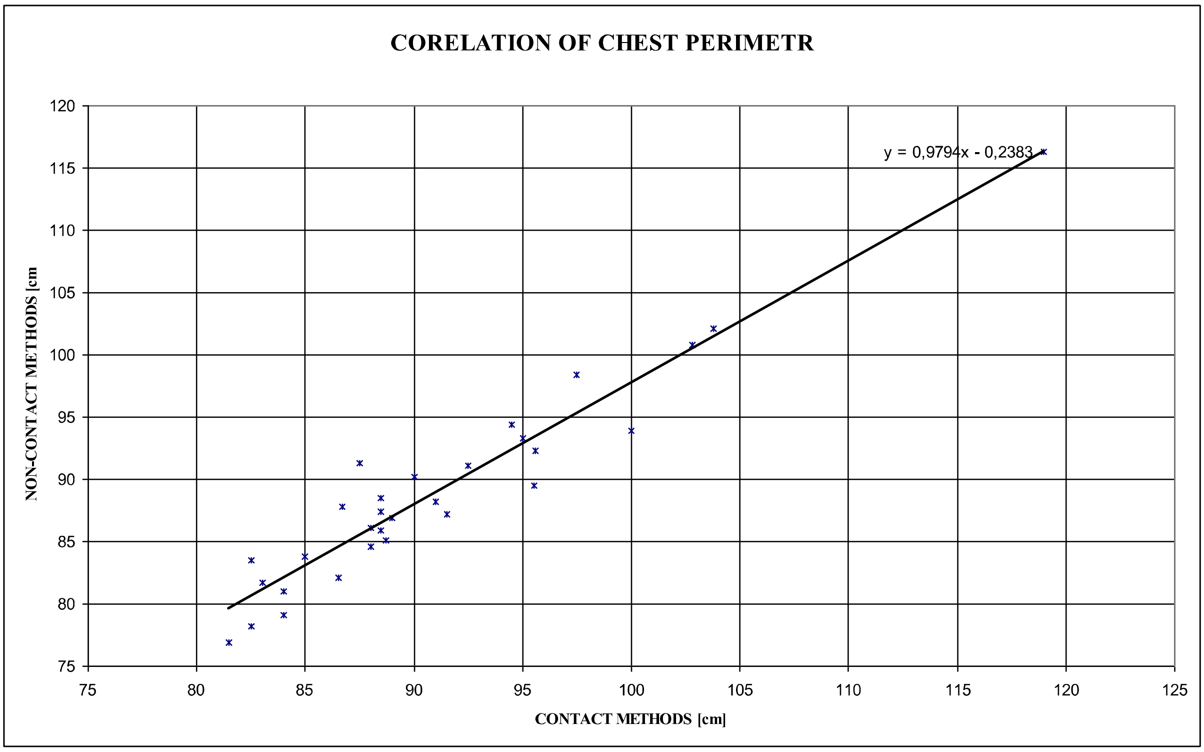
Fig. 10: *Illustration of the average values of body dimensions measured by contact and non-contact methods*

Correlation between contact and non-contact methods for figure height and chest girth is also illustrated. See Charts Figure 11 and 12. [1]



Source: Own based on [1]

***Fig. 11:** Correlation of Figure Height*



Source: Own based on [1]

***Fig. 12:** Correlation of Chest Perimeter*

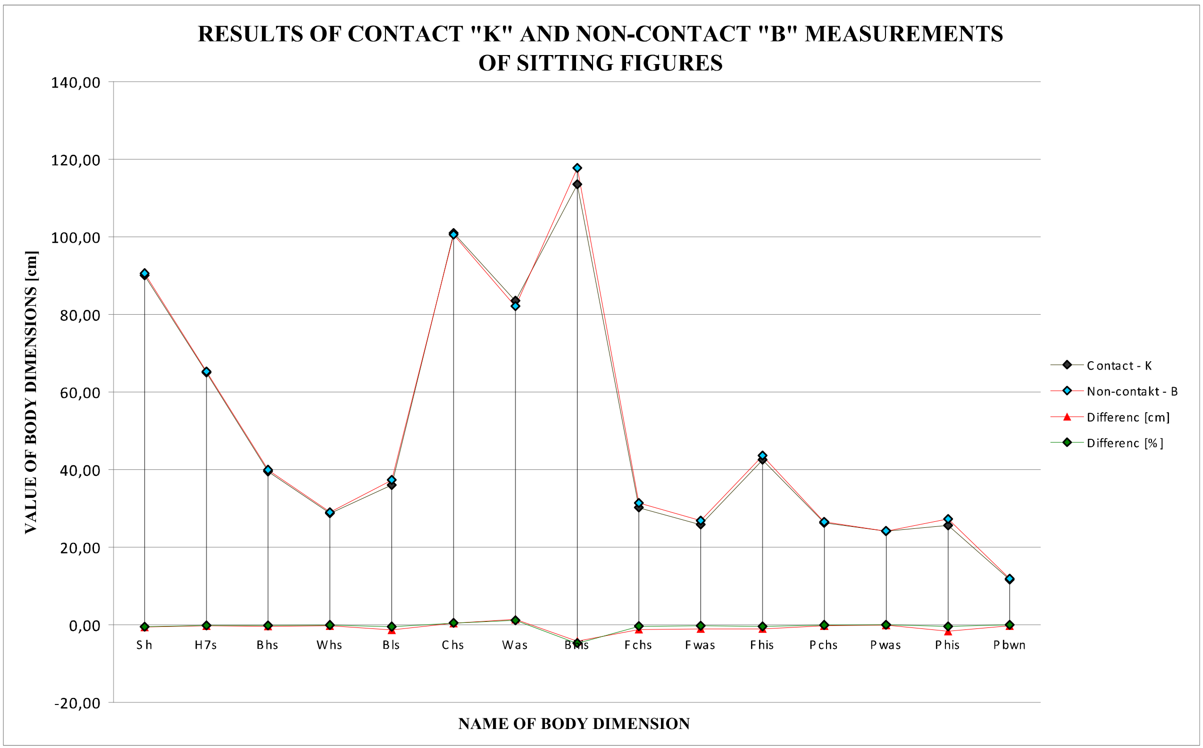


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Fig. 13: *Results of contact K and non-contact B measurements of sitting figures, differences in centimetres and percentage*

Fifteen measurements consisting of: ***four heights*** *(sitting height Sh, height of the 7th cervical vertebra when sitting H7s, breast height when sitting Bhs, waist height when sitting Whs),* ***one lengths*** *(back length Bls),* ***three girths*** *(chest girth when sitting Chs, waist girth when sitting Was, biaxial girth of hip when sitting Bhis),* ***seven widths*** *(frontal width of chest when sitting Fchs, frontal width of waist when sitting Fwas, frontal width of hip when sitting Fhis, profile width of chest when sitting Pchs, profile width of waist when sitting Pwas, profile biaxial of hip when sitting Phis, profile biaxial width of neck Pbwn).*

Errors which occurred during the process of non-contact scanning of the human body surface can be attributed to [1]:

- Equipment errors δ_1
- Errors during calibration δ_2
- Errors during scanning δ_3
- Errors due to movement of examined person δ_4
- Errors by the person carrying out scanning δ_5
- Errors when evaluating scans δ_6

According to the laws of mathematical stability, the resulting error in the direction of the axes X, Y, Z is given by the sum of named fractional errors:

$$\delta = \delta_1 + \delta_2 + \delta_3 + \delta_4 + \delta_5 + \delta_6 \qquad (6)$$

The resulting error variance in the direction of each of the axes is given by fringing coefficient of the independent fractional errors:

$$\sigma^2 = \sigma_1^2 + \sigma_2^2 + \sigma_3^2 + \sigma_4^2 + \sigma_5^2 + \sigma_6^2 \quad (7)$$

Conclusion

The paper concerns an area which is very relevant in all branches and areas of our lives. The human body is the focus of attention not only in medicine and anthropology, but also for those who want to define their appearance with clothing. In addition, when working and in entertainment the human body is the main focus of attention.

Even though it is a method which initially seems demanding to execute and process, it is a new and promising technique that requires both teamwork and absolute dedication of experienced personnel for success.

The chosen method of non-contact scanning utilized for the human body surface is challenging and requires further scientific research work. Closer evaluation and analyses of the method and its use is recommended. This is especially so for somatometric examinations when determining the dimensions and shapes of a certain population or when industrial and tailored clothing, and while calculating dimensions applied to ergonomics are concerned. It is challenging also to think of opportunities to use new equipment of a “body scanner” with CAD systems for projecting clothing or its use when selling apparel not only for healthy, but also for handicapped persons.

The MaNescan System can be used:

- anywhere where the human body surface is the subject of research,
- for scanning men, women, boys and girls including evaluation in 3D CAD system,
- for making measurements handicapped – sitting – especially those in wheelchair,
- in the clothing industry for tailoring made-to-measure clothes by so called MTM method,
- as a teaching aid for the following:
  - **Construction of clothes** – methods of human body surface measurement, evaluation of body posture and its variability
  - **CAD systems in the clothing industry** – sequencing on the MTM method – a made-to-measure way of production of clothes and subsequent sale

The results of scanning and measurements can be used for monitoring changes in human morphology, while investigating somatoscopic features, for measuring in anthropometry, somatometry and ergonomics and other applications. Generally, the results have application in anthropology and in the clothing industry.

Literature

[1] NEJEDLÁ, M.: *Contactless method of scanning the surface of the human body for the need of the application*. Palacký University Olomouc, Department of Anthropology and Health Education, Doctoral Thesis, pp. 32-33, 69-70, 75, 108-109, 112, Olomouc, 2008.

[2] ČSN 800090 *Metodika měření tělesných rozměrů mužů, žen, chlapců a dívek.* Federální úřad pro normalizaci a měření, Praha, 1993.

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Princip tělesného skeneru MaNescan®

Práce se zabývá problematikou skenování povrchu lidského těla na systému MaNescan, jehož základní filosofie spočívá ve využití metody 2D aktivní triangulace založené na cylindrickém principu. Výstupem jsou 3D data exportovaná do 3D programu CATIA a zobrazení stojící nebo sedící postavy v digitální podobě. V tomto 3D prostředí je ukázka manipulace s celým objektem, jeho proměřování a hodnocení přesnosti měřených tělesných rozměrů bezkontaktní metodou v porovnání s měřením metody kontaktní. Je naznačena cesta, jak bezkontaktně změřit naši populaci a jak získat podklady pro účely antropometrie, tj. pro sledování zákonitostí růstu lidského těla a jeho variability a účely aplikované antropologie, tedy při projektování oděvů, prádla a v ergonomii při projektování strojů a zařízení.

Prinzip des Körperscanners MaNescan®

Die Arbeit beschäftigt sich mit der Problematik des Scannens des menschlichen Körpers mittels des Systems MaNescan, dessen Grundphilosophie in der Nutzung der aktiven 2D-Triangulation-Methode, die auf einem zylindrischen Prinzip basiert. Das Ergebnis sind 3D-Daten, die in das 3D-Programm CATIA exportiert werden, und die Visualisierung der stehenden oder sitzenden Gestalt in einer digitalen Form. In dieser 3D-Umgebung wird die Manipulation mit dem ganzen Objekt, sein Abmessen und die Auswertung der Genauigkeit der gemessenen Körperproportionen mittels einer kontaktlosen Methode im Vergleich mit der Messung mittels einer Kontaktmethode veranschaulicht. Es wird ein Weg angedeutet, wie unsere Population kontaktlos zu messen und wie die Unterlagen für Zwecke der Anthropometrie, d.h. für die Beobachtung der Gesetzmäßigkeit des Wachstums des menschlichen Körpers und seiner Variabilität, und für Zwecke der angewandten Anthropologie, also bei der Projektierung der Kleidung, der Unterwäsche und in der Ergonomie bei der Projektierung der Maschinen und Einrichtungen zu gewinnen.

Zasada działania skaneru ciała MaNescan®

Praca omawia problematykę skanowania powierzchni ciała systemem MaNescan, którego podstawowym założeniem jest wykorzystanie metody aktywnej triangulacji 2D opartej na zasadzie cylindra. Rezultatem badania są dane w formie 3D, eksportowane do programu CATIA, obrazujące pozycję stojącą lub siedzącą w formie cyfrowej. W środowisku 3D ukazany jest przykład manipulacji całym obiektem, jego pomiarów i oceny dokładności pomiarów wielkości ciała przy pomocy bezdotykowej metody w porównaniu z pomiarami metodą dotykową. Przetarto drogę prowadzącą do bezdotykowego uzyskiwania danych dotyczących naszej populacji oraz danych na cele antropometrii, w tym monitorowania prawidłowości rozwoju ludzkiego ciała oraz jego zmienności na cele antropologii stosowanej np. przy projektowaniu odzieży, bielizny oraz w ergonomii przy projektowaniu maszyn i urządzeń.