How to cite this article:
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Title of article: „Parametryczny biomechaniczny model ręki – metoda pozyskiwania danych antropometrycznych" ("Parametric biomechanical model of hand – method of acquiring anthropometric data")
Mechanik, Vol. 91, No. 1 (2018): pages 32–34
DOI: https://doi.org/10.17814/mechanik.2018.1.5

Parametric biomechanical model of hand – method of acquiring anthropometric data

Parametryczny biomechaniczny model ręki – metoda pozyskiwania danych antropometrycznych

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Described is the author's method of obtaining anthropometric data of hand, useful in modeling of ergonomic objects. This method is the preferred alternative to the currently used reverse engineering in the modeling process.
KEYWORDS: parametric model, reverse engineering, anthropometry, ergonomic object

Every day we use many objects that should be ergonomic and comfortable to use. Such objects can cooperate with various parts of the human body. A large group of them is fitted to the upper limb. The authors decided to focus on objects handled. In the literature, the hand is called "the distal part of the thoracic limb" [1]. It consists of the palmar (inner) and dorsal (outer) parts [1].

Many objects require full-hand operation, which is why the research has focused on both parts. Hand operated objects can be given ergonomic features tailored to the person. It is said then about personalization. Users of such facilities are usually people with disabilities. Due to the physical limitations of such persons, it may be necessary to adapt the facility to an individual case to ensure "normal" use [2].

Technical progress raises the requirements for newly constructed and manufactured objects. Due to the rapid development of design methods and manufacturing technology, products are increasingly well-suited to the human body (including the disabled) through the geometric form, dimensions and choice of materials.

A typical approach to the design of ergonomic objects that faithfully imitates the surface of the human body involves the acquisition of geometric information in the reverse engineering process [3]. Digitalization may be subject to the human hand or its negative impression in the deformable material [4]. On the basis of the hand model, it is possible to develop a model of the object fitted to the generalized geometric form of the human body (e.g. using Boolean operations). This approach includes the involvement of the person being measured in the design process. In addition, when there is a need for any changes in the characteristics of the already completed (static) model of the hand or object created, the entire process should be re-performed, starting from the digitization of parts of the human body. This process is presented in a block diagram (fig. 1).

After creation of the real object (the target product or its prototype), verification of its ergonomics usually takes place. This process is of an iterative nature and in the case when the user of the object finds the limitations of convenience of use, it is necessary to restart the said process (ultimately to obtain more ergonomic features of the object). In some cases, the scanning will take place repeatedly.

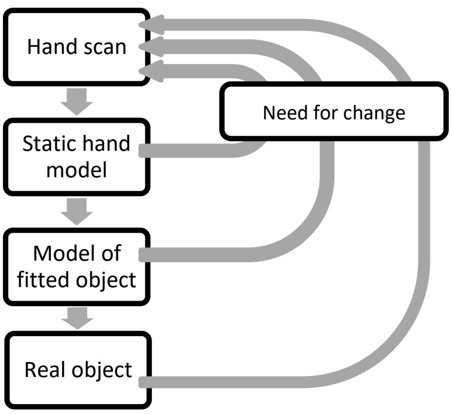

Fig. 1. Simplified block diagram of the method of designing objects fitted with the use of reverse engineering

Classic approach

With a view to improving and accelerating the design process, the authors developed a parametric model of the human hand in the CATIA v5 environment (fig. 2) to eliminate the need to conduct the reverse engineering process every time [5, 7]. Due to the model, one can simulate the form of any human hand in all its anatomical positions (fig. 2). This proprietary tool, developed in the framework of earlier research [4, 5], allows to obtain a virtual model of the human hand, regardless of its dimensions and proportions; it can be left or right hand. Kinematical constraints connecting parts of the model were chosen so as to simulate articular joints in a realistic way. In the interphalangeal joints (i.e. between pairs of phalanges) movement is performed in relation to one axis, as it is in reality. In the case of metacarpophalangeal joints (i.e.

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connecting the metacarpal joints with the phalanges of individual fingers), movement with respect to two axes was allowed [6]. The model was made on the basis of a single digitalization of a regular shape hand, belonging to a person with dimensions characteristic of the 50th percentile.

Fig. 2. Parametric hand model

Having a parametric model – treated further as a tool and a reference object – you can model new objects in a relatively easy and repeatable way, as well as modify existing ones (assuming that they have or create their virtual models). The developed tool also makes it possible to verify the ergonomic features of an object during its design and adjustment to the individual needs of a given person.

Such a tool saves time needed for digitization (and its possible repetitions), but it was still time-consuming to collect anthropometric data. Commonly used measuring methods assume the use of conventional measuring tools (e.g. vernier calipers). Hand measurements in dozens of places are time-consuming, difficult, inaccurate and require a lot of commitment from the person being measured.

In the case of the classical measurement method, the person for whom the ergonomic object will be modeled is able to independently make the data available to the designer. This approach was always associated with significant errors, e.g. due to the lack of experience of the person performing the measurements, and also required additional involvement from her.

Another possibility was to meet the target recipient of the ergonomic object with the designer in order to measure the appropriate volumes. It was also associated with unnecessary involvement of the person subject to measurement.

Developed method

The authors have developed an alternative measuring method (fig. 3). It aims to minimize the involvement of the person being measured in the design process and shorten the time needed for measurements. An additional improvement should be enabling remote cooperation between the person for whom the object is designed and the designer.

As part of the research activities, it was necessary to develop a "tool" that would limit the participation of the person subject to measurement, and at the same time enable quick and accurate acquisition of the desired anthropometric data. It should also be possible to provide data remotely.

In connection with this, some assumptions were made:

- human hand photographs should be used for measurements as the basic source of anthropometric data,
- the hand when taking a picture of its dorsal part (which is sufficient) should rest on a flat surface,
- photos can be delivered to the designer by e-mail,
- a single photograph, taken in a specific way, should provide all the necessary quantitative data.

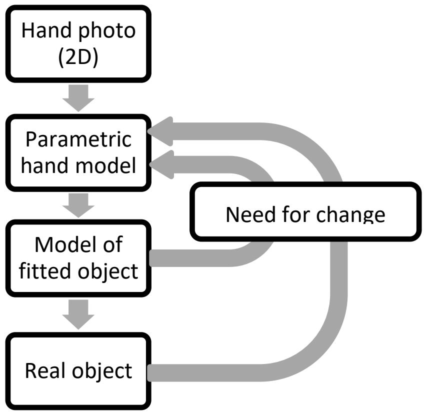

Fig. 3. Simplified block diagram of the developed method

It has been experimentally determined that the position of the hand on a flat surface does not significantly affect the dimension values read from the photo.

During the development of the measurement method, among others using a single photo of the dorsal part of the hand. To take a picture, place your hand flat on a sheet of paper (preferably in a grid) and then take a picture from above into the dorsal surface of the hand (fig. 4). Any picture taken with any device should be sent electronically to the designer.

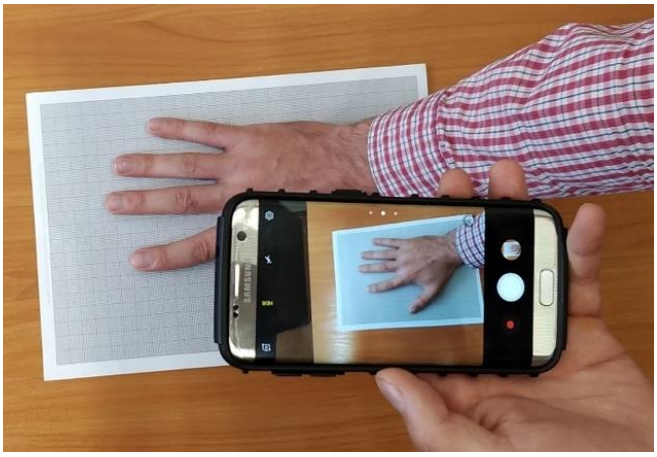

Fig. 4. Method of taking pictures

Uploaded image should be imported to previously developed in CATIA v5 environment tools (wireframe model).

The following step is to fit the sheet of paper in the picture to the grid lines in the model and to scale it so that the grid lines of the model overlap with the grid on a piece of paper. (If you use a smooth sheet of any format, you must first adapt the rectangle in the sketch belonging to the measurement model to the dimensions of the sheet).

Next, the photo is placed in the space of the model in such a way that the edges of the sheet overlap with the previously defined rectangle on the sketch (the boundaries of the paper must be visible in the picture). Thanks to such adaptation of the photo to the space of the skeleton model, it is possible to read the dimensions of the parts of the hand.

Sketch points in the model must be matched to the characteristic places of the hand. Previously prepared dimensional constraints in the sketch were defined as reference ones, which allows free shifting of their characteristic points (fig. 5). After such a model update, the values of dimensional constraints are automatically transferred to the design table (in the sense of the CATIA system), where they are assigned parameters corresponding to the names of parametric parameters of the hand (fig. 6). Therefore, you can export a design table from an external file (e.g., TXT or XLS). The anthropometric data obtained this way (thanks to this) can also be used in a different way, not only as part of the proposed method.

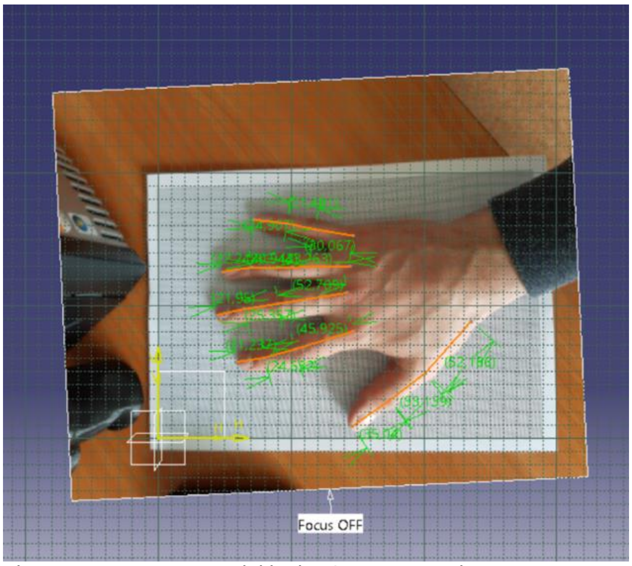

Fig. 5. Measurement model in the CATIA v5 environment

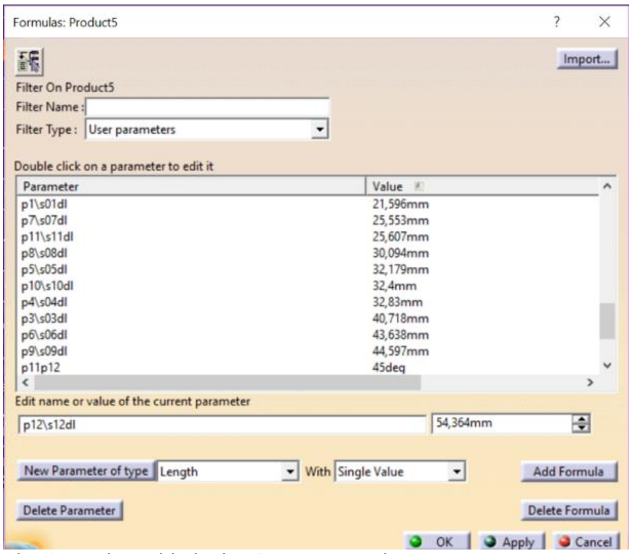

Fig. 6. Design table in the CATIA v5 environment

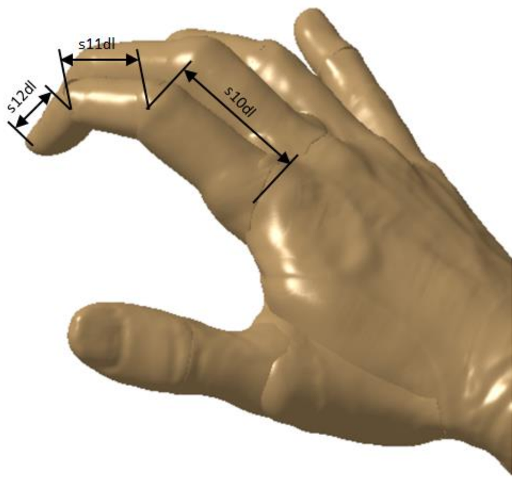

Fig. 7. Visible changes in the length of the hand phalanx models

Therefore, the data file read from the photo can be imported into the parametric hand model. After importing the data and updating the model in the CATIA v5 environment, the hand model automatically adapts to the given case, faithfully simulating the geometric form of the hand whose dimensions were obtained (fig. 7).

To check the accuracy of the proposed measurement method, the results obtained using the proprietary tool and conventional methods were compared. The differences in values were within the limits of measurement error of the conventional method.

Conclusions

A method for acquiring anthropometric data, alternative to commonly used methods (related to reverse engineering) was developed. The main purpose of the search for a new method was to simplify and accelerate the measurement process. In the CATIA v5 environment, a model was developed to serve as a measurement tool. The input data for the measurement model is provided as a single hand photo. The output data is returned in an ordered form (e.g. as a spreadsheet, in which the necessary anthropometric data are compiled). Research has proved the effectiveness of the method described.

Developed method, using the parametric model, also allows for a completely remote cooperation of the designer with the person, for whom the object is designed. Due to the elimination of the most time-consuming stage, which is digitization, this method is much faster and less embarrassing for people than any conventional method.

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Translation of scientific articles, their computer composition and publishing them on the website www.mechanik.media.pl by original articles in Polish is a task financed from the funds of the Ministry of Science and Higher Education designated for dissemination of science.

Ministry of Science and Higher Education
Republic of Poland