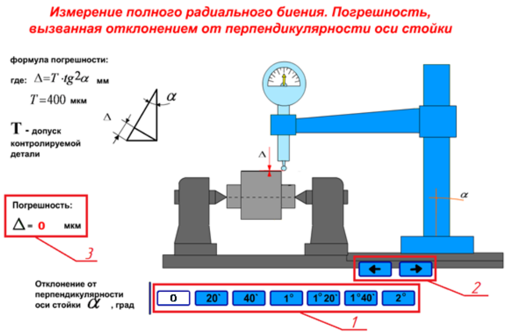

Рисунок 3 – Компьютерная визуализация погрешности, вызванной отклонением от перпендикулярности оси стойки контрольного приспособления (в мультимедийной платформе Macromedia Flash)

Рассмотрим составляющую погрешности измерений при измерении полного радиального биения – погрешность, вызванная отклонением от перпендикулярности оси стойки. В первоначальном положении ось стойки перпендикулярна основанию (рисунок 3).

При помощи кнопок на панели 1 (рисунок 3) задается отклонение от перпендикулярности в градусах, кнопки на панели 2 позволяют передвигать стойку в различных направлениях, причем Δ выдается на экран в виде численного значения (панель 3, рисунок 3). В результате применения данной методики обеспечивается высокая наглядность процесса возникновения погрешности и одновременно ее расчет

УДК 535.3

THE UNCERTAINTY OF ANTHROPOMETRIC PARAMETERS MEASUREMENTS IN DIGITAL BIOMETRIC SYSTEMS

Saukova Y.[1], Sutkovski M.[2]
[1]Belarussian National Technical University
Minsk, Belarus
[2]Warsaw University of Technologies
Warsaw, Poland

On the base of Warsaw University of Technologies in the 3D Technologies Laboratory scientific investigation of designed digital biometric systems are carried out. It is necessary to solve the task of metrological traceability in the part of uncertainty estimation.

1 The measuring task. The measurand is an anthropometric parameter namely the coordinates of the object (patient's body) in three-dimensional space. A series of characteristic anatomical points is marked on the examined body with special non-invasive markers. Analysis of the examined posture is performed as a series of parameters calculated on the base of the measured points of the body. Measurement is based on the determination of the digital image pixel coordinates corresponding to the object point relative to relative zero reference point. The relative zero reference point is normally assumed as one of the measured points – i.e. P_0 is denoted by reference (x_0, y_0, z_0). Other points are represented as theirs relative position in space.

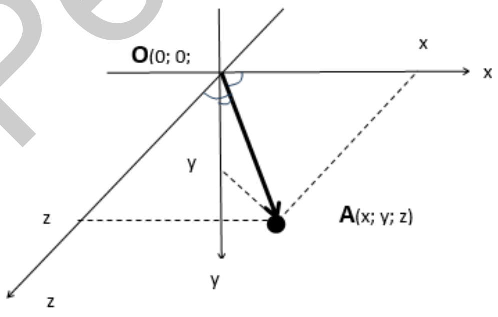

Figure 1 - Graphical description of the measurand

2 The mathematical model and the data. The anthropometric parameter namely coordinates (x, y, z) of the object ((point marked onto the examined' body) point in three-dimensional space represents the distance from relative point zero of the count down to the desired point and is determined by the length of the vector OA. The model measurement result mathematical expectation has the form (look figure 1):

$$A_x = x - 0;\ A_y = y - 0;\ A_z = z - 0 \qquad (1)$$

Noting the specificity of transformation from 2D to 3D spaces the correction factors k_x and $k_y$are entered for the z coordinates. A combined uncertainty of the measurand represents a locus of points (region) in 3D space and consists of uncertainties in each coordinate:

$$u_c(A) = \sqrt{u^2(x) + u^2(y) + u^2(z)} \qquad (2)$$

3 Analysis of the input quantities and their uncertainties. Each input value (*x, y, z*) involved in the measurement process depends on other input quantities which are sources of variability. In general original models of mathematical expectations for each of the coordinates have (on example x) the following form:

$$x = x_{ind} + c_{x1} + c_{x2} + c_{x3} + c_{x4}, \qquad (3)$$

where x_{ind} (y_{ind}, z_{ind}) – point estimates of the measurand; c_{x1} (c_{y1}, c_{z1}) - corrections on errors of measuring instruments; c_{x2} (c_{y2}, c_{z2}) – corrections on subjective errors; c_{x3} (c_{y3}, c_{z3}) - corrections on errors caused by the imperfection of the measurement method; c_{x4} (c_{y4}, c_{z4}) - corrections on errors caused by the influence of the measurement conditions.

It would be logically to assume the input values x, y, z have the same set of sources of variability. However, we should consider the fact that the 3D space is converted ultimately into a two-dimensional digital images. In this regard, the z-coordinate has an additional source (the correction factor) associated with this transformation. The variability factors (correction of error) were grouped according to sources of origin for analysis. The input quantities - point estimates of the measurand x_{ind}, y_{ind}, z_{ind} are determined experimentally as a mathematical expectation of n=2 measurements according to the formula:

$$x_{ind} = \overline{x} = \frac{1}{n}\sum_{1}^{n} x_i \qquad (4)$$

where x_i, y_i, z_i- the results of the i-th observation at a control point along the axes 0x, 0y, 0z respectively. Standard uncertainties $u\,(x_{ind})$, $u\,(y_{ind})$и $u\,(z_{ind})$ (on example of x-coordinate) are calculated as the standard deviation by the formulas:

$$u\,(x_{ind}) = \frac{x_i - \bar{x}}{\sqrt{2}} \qquad (5)$$

For calibration of digital camera certified standard samples playback linear dimensions has been used in the measuring procedure. According to the standard samples certificate "tolerance playback linear dimensions horizontal (x-axis) is $\pm\Delta_x$, on a vertical $\pm\Delta_y$». Taking the interval from - Δ_x to + Δ_x and - Δ_y to + Δ_y rectangular probability distribution the standard uncertainties are calculated according to the formulas [1]:

$$u(c_{x1}) = \frac{\Delta_x}{\sqrt{3}};\ u(c_{y1}) = \frac{\Delta_y}{\sqrt{3}};u(c_{z1}) = \frac{\Delta_z}{k_x k_y \sqrt{3}}, \qquad (6)$$

where k_x, k_y – correction factors used to convert from 3D to 2D space.

Input variable quantities - corrections on subjective errors $\boldsymbol{c_{x2}}$, $\boldsymbol{c_{y2}}$, $\boldsymbol{c_{z2}}$. The human factor is not explicitly taken into account for this measurement task because the measurements are performed using an automated system. Input variable quantities - corrections on errors caused by the imperfection of the measurement method $\boldsymbol{c_{x3}}$, $\boldsymbol{c_{y3}}$, $\boldsymbol{c_{z3}}$ depend on several groups of factors: 1) applied technical means, equipment (digital camera, tripod, terminal, etc); 2) effects of sampling and quantization; 3) effects related to incorrect idealization of the object. The digital resolution of the camera is NxM pixels in a two dimensional format. Given the scale of digital photography object's physical dimensions n*m unit pixel can be reduced to geometrical parameters of the recorded scene. Thus, the area of digital image of n*m pixels corresponds to a region of n*m of some elementary fields of the recorded scene in a 2D format. It is necessary to consider the correction factors k_x and k_y for the z coordinates (3D). Thus, the geometric dimensions Δ_x, Δ_y and Δ_z along the three coordinate axes correspond to each unit pixels. Elementary line segments (Δ_x, Δ_y and Δ_z) for this measurement task can be considered as the nominal level of sampling (discretization). Setting the rectangular probability distribution in the intervals $\delta_x = x_{i+1} - x_i$, $\delta_y = y_{i+1} - y_i$ and $\delta_z = z_{i+1} - z_i$ the standard uncertainty (on example x-coordinate) can be calculated as a standard deviation by the formula:

$$u(c_{x31}) = \frac{x_{i+1} - x_i}{\sqrt{3}} = \frac{\delta_x}{\sqrt{3}} \qquad (7)$$

Corrections of errors caused by the influence of the tripod mounts for digital camera $\boldsymbol{c_{x32}}$, $\boldsymbol{c_{y32}}$, $\boldsymbol{c_{z32}}$ are apriority taken into account in the measurement system calibration, therefore, they are explicitly in the model not present. The terminal does not introduce variability in the results of the measurements and is only used as a means of information display.

Corrections of errors caused by incorrect idealization of the object and approximations $\boldsymbol{c_{x34}}$, $\boldsymbol{c_{y34}}$, $\boldsymbol{c_{z34}}$ are accounted for by introducing in the model correction coefficients $k_x$and k_y which in fact are the sines of the angles between the vector 0A and the coordinate axes 0x, 0y. To display the axes 0x and 0y factors $k_x = 1$ and $k_y = 1$ and are treated as constants. For the axe 0z $k_x = \frac{0X}{0A}$ and $k_y = \frac{0Y}{0A}$. If k_x and k_y are specified as constants their uncertainties are due to the geometric factor of the pixel two-dimensional graphics and calculated by formulas (8) out of the expressions for the rectangular probability distribution. Corrections on errors caused by the influence of the measurement conditions $\boldsymbol{c_{x4}}$, $\boldsymbol{c_{y4}}$, $\boldsymbol{c_{z4}}$ are apriority taken into account in the measurement system calibration, therefore, they are explicitly in the model not present. The input quantity the reference point **“0”** is determined during calibration using special tables. Its uncertainty u(“0”) is characterized by the uncertainty of the calibration tables and taken from the certificate (8).

4 Covariance. Undoubtedly, there are covariance between the input quantities, such as those associated with the presence of to determine each coordinate of the zero point of reference.

5 The combined uncertainty of the measurand. Given the above expression for standard uncertainties of the input quantities in absolute view get In the relative view:

$$\frac{u_c(A)}{\mathrm{A}} = \sqrt{\frac{(x_i - \overline{x})^2}{2x^2} + \frac{(y_i - \overline{y})^2}{2y^2} + \frac{2u\,(x_i, y_i)}{u(x_i)u(y_i)} + \frac{2\Delta^2{}_x}{3x^2} + \frac{2\Delta^2{}_y}{3y^2} + \frac{u\,(\Delta_x, \Delta_y)}{3u(\Delta_x)u(\Delta_y)} + \frac{\delta_x{}^2}{3x^2} + \frac{\delta_y{}^2}{3y^2} + \frac{u\,(\delta_x, \delta_y)}{3(\delta_x)u(\delta_y)}}$$

1. Guide to the Expression of Uncertainty in Measurement (GUM). Geneva (2nd printing 1995).