

# Computerised Data Acquisition and Processing in Measurement of Raster Scales

MINDAUGAS RYBOKAS

Department of Information Technologies

Vilnius Gediminas Technical University

Sauletekio 11, Vilnius

LITHUANIA

mrybokas@gama.vtu.lt <http://gama.vtu.lt>

*Abstract:* - The development and implementation of computerised control of measurements and the simulation and calculation of measurement of raster scales and transducers are discussed. The number of strokes in circular raster scales exceeds hundreds or thousands, so it is impossible to calibrate the scales and calculate the results using conventional methods without computer interaction. An example of the new approach to computer simulation of the circular scales calibration process with the reference measure is given, creating the model of measurement and simulating the instrumental steps performed on the object, the comparison with reference measure and the evaluation of systematic error, uncertainty, numerical and graphical presentation of the results.

*Key-Words:* -Computer Simulation, Measurement, Calibration, *Visual Basic*.

## 1 Introduction

Most of the modern technical instruments, machining units of metal cutting tools, every kind of measuring equipment, such as coordinate measuring machines, etc., linear and rotary encoders produce a great number of data values. These values between the determined (calibrated) points remain unknown during the checking process. The information received during the calibration relative to the total information available can be evaluated using information entropy. The calibration equipment that allows selecting significantly more information would be essential for better accuracy assurance of instruments used in machine engineering, geodesy and construction. Development of computer simulation and software for angular accuracy evaluation is presented further. The main concepts of circular scales measurement were chosen as the basis for developing a computer simulation (CS) system. Since scales are employed in almost all measuring systems, into the linear and rotary encoders; they play the most important role in the methods of monitoring of their accuracy parameters. The CS presented demonstrates the measurement and data monitoring of circular scales. This method can also be used for an effective monitoring of the accuracy of instrument performance.

An example of the new approach to computer simulation of the circular scales calibration process with the reference measure is given, creating the model of measurement and simulating the

instrumental steps performed on the object, the comparison with reference measure and the evaluation of systematic error, uncertainty, numerical and graphical presentation of the results. The mode of calibration is selected from the menu developed. Different methods of measurement could be simulated by the means created, investigating static and dynamic characteristics of measurement. The computer simulation system for further investigations and educational process is described expanding the analysis of intrinsic and other error influence as well as the means of mathematical data evaluation. Computer evaluates the information collected according to the method and presents it in the form convenient for assessing, transferring and taking the necessary control or correction actions.

## 2 Problem Formulation

CS must implement the means of checking the methods of measurement verifying the results achieved and their analysis. The diagram of the main elements of data processing included in the model of CS system is shown in Fig 4.1. The model consists of the information received from the object to be measured and reference information. The information is selected by the data reading sensors M1 and M2, further follows the input of the systematic constituent (from the reading sensors or generated), parallel random numbers generation, transfer and evaluation system by the software of the

CS and presentation of the results in the required form [2, 3].

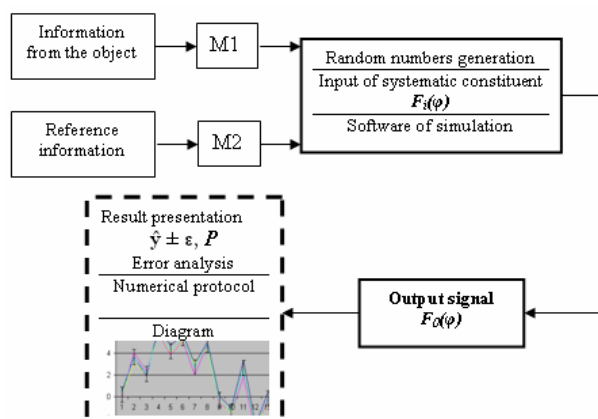


Fig. 1. The main elements included in the CS information processing system

Standard means of mathematical statistics are used for result evaluation. For engineering applications the measurement system is designed to have an input signal  $F_i(\varphi)$  that could be expressed as a general  $n^{\text{th}}$  order linear ordinary input differential equation (1), and output signal  $F_o(\varphi)$ , (2), represented by the equation developed from the error of the scale measurement by the CS means [1].

$$a_n \frac{d^n x}{dt^n} + a_{n-1} \frac{d^{n-1} x}{dt^{n-1}} + \dots + a_1 \frac{d x}{dt} + a_0 x = F_i(\varphi) \quad (1)$$

and

$$b_m \frac{d^m y}{dt^m} + b_{m-1} \frac{d^{m-1} y}{dt^{m-1}} + \dots + b_0 y = F_o(\varphi) \quad (2)$$

The coefficients  $a_0, a_1, \dots, a_n$  represent error distribution in the scale, and coefficients  $b_0, b_1, \dots, b_m$  represent errors of the scale measured by the CS system. These functions can have ratio between them expressed by the coefficient  $k$ :

$$b_m \frac{d^m y}{dt^m} + b_{m-1} \frac{d^{m-1} y}{dt^{m-1}} + \dots + b_0 y = k \left[ a_n \frac{d^n x}{dt^n} + a_{n-1} \frac{d^{n-1} x}{dt^{n-1}} + \dots + a_1 \frac{d x}{dt} + a_0 x \right], \quad (3)$$

where  $k$  will depend on variety of factors involved in the measurement and the possibility of its evaluation. Coefficient  $k$  in general case also is variable entity.  $m, n = 1, 2, 3, \dots; m \leq n$ .

The system can be evaluated by parameters of the measurement model and by Fourier analysis of input (1) and output (2) functions. The coefficients of the

Fourier series will be determined by the amplitudes of the error (introduced and measured) functions, each having a specific frequency.

The first approach for a CS system is chosen for circular scale measurement and is shown in Fig 1. The PC screen (pixel grid) can be used as a reference measure. Result evaluation is performed by a software selected and can be presented in the form of a numerical protocol, diagram, statistical evaluates such as mean value estimate, uncertainty, etc. Data distribution analysis also is performed using spectral analysis. The CS described further is designed for a circular scale parameters and accuracy analysis and simulation of its various technical parameters.

### 3 A Program for Simulating Angular Scale Measurement

This section describes the angular scale simulation program created on the basis of the method introduced earlier. The program is written in *Microsoft Visual Basic*, the language not known for its flexibility but convenient for writing fairly simple and brief programs with a visual interface.

This program is characterized by visual and data manipulation adjustments that can easily be made with the controls located on the left-hand side of the screen (see Fig 2–3). The adjustment that makes the most evident impact on the program is changing the width of the scale strokes being displayed. In general, the greater the number of strokes being used, the smaller the width of strokes should be used. The first stroke width on the list has been optimized for the maximal number of strokes that could be displayed so that the visualization remains legible. The list of stroke widths is preset in the code of the program, but it would be easy to delete existing values or add new ones if such a need ever arises. Other adjustments that influence data processing are located in the controls group *Measurement* at the lower left corner of the screen. The first control at the top moves individual strokes to the position of Microscope 1. Pressing the minus button moves the scale by one stroke counter-clockwise, while pressing the plus button moves the scale by one stroke clockwise. The next control, an option list, is involved in with performing measurement by certain microscopes. The errors can be cancelled in relation to one of the three microscopes or the error difference between split the microscopes in the last option in the list. The default option is to perform no correction in relation to Microscope 1. And the last control in the

*Measurement* group introduced a random element into data processing. The user can indicate the random error that is included in calculating the results.

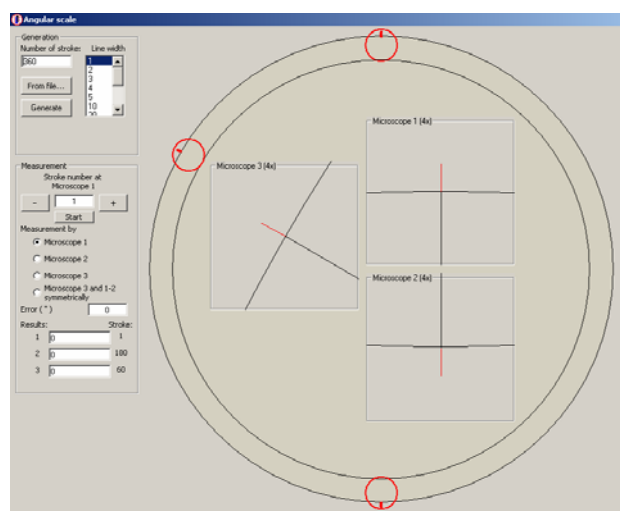


Fig 2. The start screen of the angular scale simulation program

The simulation of angular scale measurement starts at the *Measurement* control group at the upper left corner of the program window. At this point, one also has to indicate a path to the file with initial data for the strokes. The number of strokes to simulate can be chosen virtually at will programmatically. However, to be able to create a static array for calculations in the computer program the upper limit of 720 strokes has been chosen having been noted that this number represents a sensible value from a measurement standpoint (each stroke divides the circle into half a degree), and at this number of strokes individual strokes still remain visible. Therefore, mostly for the sake of visualization no more than 720 strokes should be entered. Otherwise, it becomes nearly impossible to distinguish individual strokes around the scale. The visualisation can also be adjusted by choosing a line width for strokes from the Line width list on the right of the control group. The effects of changing line width will be seen in the examples provided below. Nevertheless, no matter how many strokes are entered the program still computes the results displaying them in the Measurement group at the centre left of the screen at the three strokes near the microscopes as well as generating a results file with the results at every stroke.

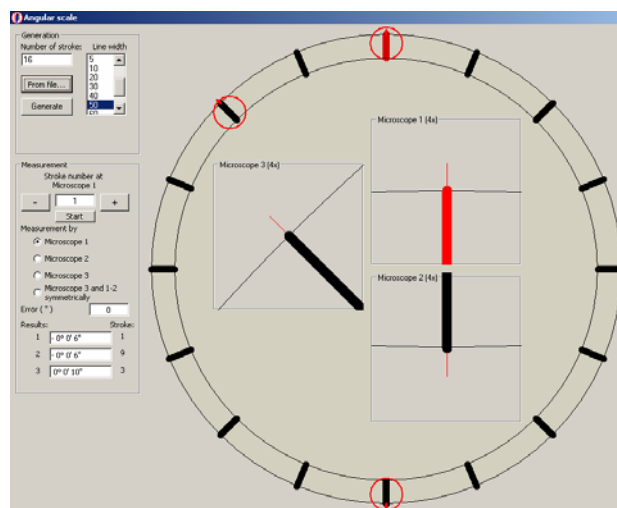


Fig 3. The program screen after generating results for 16 strokes

After the measurement simulation some of the results are displayed in charts in Fig 4.9 and 4.10. Once again, to make the visualization legible only 16 and 30 values have been taken, but the upper limit currently set in the program is 720 values; this limit can easily be changed in the code for this program without affecting program's functionality.

## 4 Conclusion

A computer simulation method applied to the new raster scales measurement method is proposed together with data processing and evaluation. Data acquisition and interactive mode of processing permit to implement a wide range of metrological and education tasks. Measurement simulation can be used for the development of new instrumentation means for circular scales measurement and development of more efficient practical data assessment structure using mathematical statistics.

### References:

- [1] Giniotis, V.; Marčiukaitis, G. Computer Simulation of Scales Measurement. *Geodesy and Cartography*, 1999, No 1, p. 3–8.
- [2] Just A.; Krause M.; Probst R.; Wittekopf, R. Calibration of High-Resolution Electronic Autocollimators against an Angle Comparator. *Metrologia*, Vol. 40, 2003, p. 288–294.
- [3] Zemanek H., Measurement Technology – Information Technology. In: Proceedings of the XVI IMEKO World Congress, held in Vienna on 25-28 September, 2000, Vol VIII. Vienna: KOPITU, 2000, p. 405–413.