Bulletin of the *Transilvania* University of Braşov • Vol. 11 (60) No. 1 - 2018
Series I: Engineering Sciences

IT INTERFACE FOR AUTOMATIC NUMERIZATION ON LOW COST COORDINATE SCANNING SYSTEMS

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Abstract: *The paper presents a stage of the research for quality inspection processes optimisation for some components with application in industry, optics and medicine. The experimental equipment consists in a in a two-axis coordinated positioning system, developed within pre-research activities. The research was focused on developing some software and hardware flexible interfaces, for automatic inspection processes control and also for automatic and efficient generating and interpreting data results.*

Key words: *software, programming, probes, scanning.*

1. Numerization Process

The need to continuously improve product quality along with services has made the quality assurance requirements for production increasingly severe. In this context, the process of inspecting the dimensional and functional parameters of components with an important role in the finished products component with applications in all fields has continuously increased its role. Besides, the problem of product design in accordance with current commercial requirements became very important one [6], [8].

To respond to all these requirements, in the context of increasing the efficiency of production processes, in the last few years it was found the solution of using complex and efficient systems for dimensional inspection and for CAD-CAM models automatic reproduction for different scanned in coordinates probes [4]. For this reason the incidence of CMM use in the last years has more and more increased, especially those with LASER principle measuring devices [7]. The main advantage of such systems is that these can be successfully used for application in different domains. Three of these are the most common: industry (auto, aeronautics, robotics, non conventional energy systems etc.), optics (elements that compose elementary systems (lens, parallel planes, mirrors, prisms etc.), biomechanics (protetics, orthoses) [1], [5].

However, the main disadvantage of such complex and performance systems is that of high costs, not just purchasing, but also maintenance standpoint. For this reason, our research has been geared towards developing low-cost coordinate scanning systems,

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with the possibility of using them both in the educational environment and in research activities. In this context, our current research concerns strictly the development of IT interfaces (especially software). First of all, it is about the automatic command and control of the scanning processes, especially the processing of the data specific to the results of the measurement of the coordinates of the axes defining the scanned surface of the relevant probe or component [2], [4], [6].

2. Equipment

For the researches, the equipment, as second hand, is low cost, very useful for both for research and educational activities. It was considerable improved during the last years, due to academic researches and educational Diploma projects.

As study object for the research on the product quality inspection is considered a gauge meaning a low-cost coordinate measuring system that was step by step developed in the last years, during different research activities. Initially, a simple robotic positioning axis (YAMAHA, Japan) was acquired by the University, after that, it was disposed a translation system along a perpendicular direction with manual displacement. The latter system consisted as a Diploma Project to transform the robotic axis into a two Cartesian axis positioning system [3]. The next step was to adapt a command system for automatic displacement along the second axis, by implementing a specific hardware device. It consists by the following elements: an Arduino Uno micro-controller, a developing board and a stepper engine ordering system with specific driver (commanded by the micro-controller). This was considered as another Diploma Project, continuing the first project. Besides, to complete a low cost automatised coordinate measuring system, actually, different measuring systems can easily be adapted by means of special, adjustable supports with magnetic sole (Figure 1).

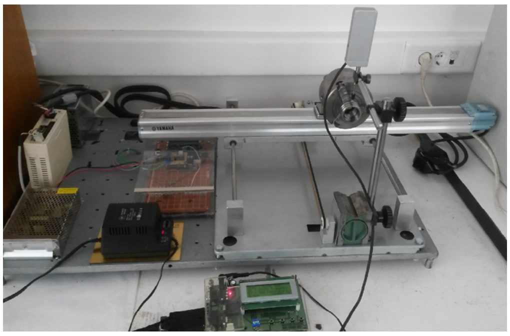

Fig. 1. *Improved low cost coordinate measuring system as research object*

The actual stage of research addresses the aspect of inspection cycles and data interpreting due to software interfaces, meaning IT solutions for coordinate numerization automatization and improving. Software interfacing as actual research stage is presented in the paper.

At present, two software applications have been developed to control the two-axis movement process for coordinate scanning. The first is related to robotic axis action (along the OX axis), and the second is to move the step-by-step movement of the whole assembly along the OY axis. In this context, the command principle is the following: it is considered that the necessary scan area of the probe contains a number of *n* scan vectors each one including a number of *m* measuring points (Figure 2).

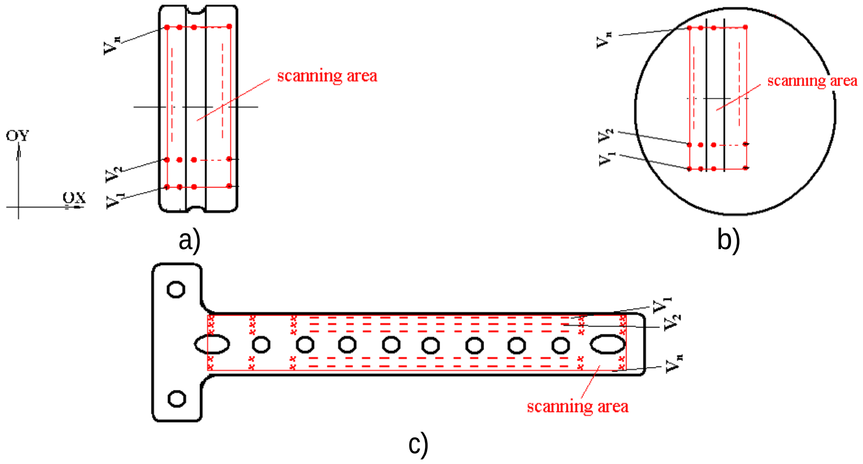

Fig. 2. *Scanning area for probes with application in different domains:*
a) industry (inner bearing ring); b) optics (spherical lens);
c) biomechanics (fibula prosthesis)

At the start of a scan cycle, the YAMAHA robotic axis trains the conveyor step by step (to each measuring point corresponding to the first scanning vector). At the end of the first scanning vector, the second entraining system commands the positioning of the conveyor along the OY axis for scanning along the next vector. The process continues similarly until the last scan vector is reached.

3. IT Application Development on the Existing System

3.1. Hardware Interfacing

The YAMAHA T5 robotic positioning system (for entraining and positioning along OX axis) includes a DCC motor, commanded by an ERCD high precision controller, based on a 32 bits RISC processor. When connected to a single FLIP-X linear axis system, the ERCD controller performs different positioning tasks with various mechanical parts and devices.

The second axis has a stepper motor for entraining along OY axis, commanded by an electronic developing board, congaing as main component an Arduino UNO R3 controller that can be programmed. Step-by-step start positioning command for the OY axis can be easily made due to an infrared telecomm and, with transmission distance up to 8 meters.

3.2. Software Interfacing

In terms of command interfacing, in the paper there is presented an example of software application to perform an automatic scan cycles on 5 vectors of 10 measuring points, applicable for all three types of probes exemplified in Figure 2.

For YAMAHA robotic axis, its programming was made in accordance with the following algorithm: indexing the position in the 10 measuring points, along OX axis must be ensured 5 times, each time for each scanning vector. Experimentally it was estimated a time of about 7 seconds for each measuring point, so that, for each next point indexing, such a temporisation must be programmed. For a proper scanning, the speed of displacement to each point must be low (about 20% from maximum robot speed). In this context, a total time for a complete scanning along each vector could be estimated to about 100 seconds. Scanning procedure for one scanning vector means a sub-routine programming (saved as program No 1, see Table 1) being called for each scanning vector (five times). This was considered as another programming sub-routine. The main program must include the subroutines which algorithm is described above. Its exemplification is given in Table 1:

Main program for command displacement along OX axis Table 1

No.	Programming line	Significance
1	ORGN	The conveyor transporting the probe must to start from the origin of the robotic system
2	TIMR 300	Temporisation of 3 seconds
3	CALL 2, 5	Calls the programming sub-routine no. 2, for 5 times
4	TIMR 300	
5	END	

The programming subroutines are presented in Tables 2 and 3:

Sub-routine for programming point-to-point position indexing Table 2

No.	Programming line	Significance
1	MOVA 1, 10	Displacement to the first scanning point with a speed of 10% from the maximum robot speed
2	TIMR 1000	Temporisation of 10 seconds before the next position indexing
3	CALL 3, 10	Calls the programming sub-routine no. 3, for 10 times
4	END	

Sub routine programming the step by step displacement along OX axis Table 3

No.	Programming line	Significance
1	MOVI 2, 20	Relative displacement at point no. 2, having the incrementing step from the previous point, with the speed of 20% from the maximum robot speed
2	TIMR 700	Timing of 7 second for each measuring point
3	END	

For the proper positioning along OX axis, the coordinates of the absolute and relative points for displacement were previously defined, according to the necessary conveyor position reported to the scanning device.

For the second axis (along OY), the Arduino controller was programmed to command the stepper rotation, so that the conveyor to be translated along OY axis, each time when a new scanning vector must begin. Taking into account that for each scanning vector (along OX axis) the necessary time is about 10 seconds, this timing was considered for each step by step translation along OY axis. The programming included four selective sub-routines for different translation step size: 1 mm, 2 mm, 3 mm or 4 mm, depending by the scanning area, in fact by the necessary distance between scanning vectors. Sub-routine programming of a step displacement invoked an algorithm to determine the necessary number of steps to run the stepper motor. To determine the number of steps means, first of all to determine the angle of rotation of the stepper motor's axis pinion (θ_p), so that the gear ensures the necessary rotation corresponding to the increment along OY axis. Knowing that the mechanism is composed by two reports of transmission, meaning a transmission between the pinion and an intermediary wheel, and also a transmission between the intermediary wheel and the belt pulley, it was possible to establish a calculus relation. The second transmission report can be defined in the relation (1) and the first transmission report can be defined in the relation (2):

$$i_2 = \frac{\theta_{r\_i}}{\theta_p} = \frac{\phi_{r\_i}}{\phi_p}\,, \tag{1}$$

where θ_{r_i} represents the rotation angle of the intermediary wheel and ϕ_{r_i} and ϕ_p are the diameters of the two wheels;

$$i_1 = \frac{\theta_{r\_c}}{\theta_{r\_i}} = \frac{\phi_{r\_c}}{\phi'_{r\_i}}\,, \tag{2}$$

where θ_{r_c} represents the rotation angle of the pulley and ϕ'_{r_i} is the second diameter step of the intermediary wheel.

Knowing that the necessary displacement (y) along OY axis depends by the pulley's diameter (R_{r_c}) and the it's rotation angle (Equation 3), thus means that the rotation of the stepper motor's axis pinion (θ_p) can be calculated due to relation (4):

$$y = R_{r\_c} \cdot \sin(\theta_{r\_c}); \tag{3}$$

$$\theta_p = \frac{\phi_{r\_i}}{\phi_p} \cdot \frac{\phi'_{r\_i}}{\phi_{r\_c}} \cdot \arcsin\left(\frac{y}{R_{r\_c}}\right). \tag{4}$$

Knowing the dimensions of the wheels and applying the relation (4) we have obtained the number of steps and also the rotation angle of the stepper, corresponding to the necessary displacement steps along OY axis (Table 4).

No of necessary steps for the necessary step increment Table 4

Rotation stepper angle [°]	Number of steps	Displacement along OY axis [mm]
7.2	4	1.06
14.4	8	2.12
19.8	11	2.9
27	15	3.93

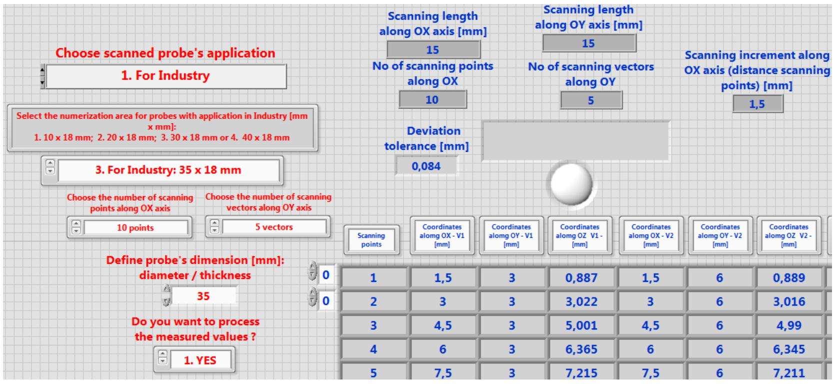

Fig. 3. *Developed software interface for data processing - general view*

Another aspect referring to the scanning process automation and improving means the software interface, as instrument for a complete and conclusive, efficient data processing. For this, a software application was developed in Lab VIEW environment, allowing reading from files data, processing them and displaying all the necessary and conclusive results referring to the scanned probe (Figure 3) [9].

The software interface was programmed as main research activity, to be a user friendly interface, due to which he could select all conditions and parameters referring to the inspection process. These can be defined via several text and dialog boxes, in red (Figure 3). The first one allows selecting the application of the scanned component (for industry, for optics or for biomechanics). A text-box is meant to guide the user to establish the dimension order of the scanned probe in function of its application. The order of dimension must to be established in the second text-box (Figure 4). The third text-boxes allow to the user to define the scanning parameters (the step increment along OX and along the OY axes), meaning the number of scanning points / vector (along OX) and the number of scanning vectors (along OY).

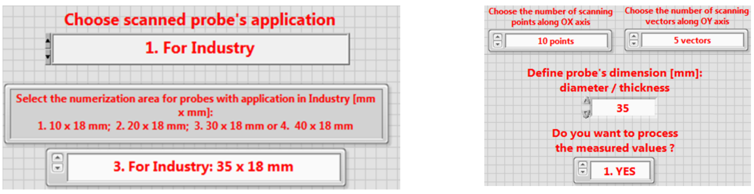

Fig. 4. *The text-boxes for selecting the scanned probe's dimension and to save or not the processed data*

Another text-box is provided to introduce the dimension of the probe (length, diameter or thickness) and the last text-box allows to select to save or not the processed data after the software running. Excepting the text-box referring to the probe's dimension (being defined as a numeric input variable), all the others text-boxes were defined as *Text Ring* variables, each one addressing switch-case programming structures. The first one means 3 cases, referring to the 3 examples of application fields (industry, optics, biomechanics), the second addresses 10 cases of dimension ranges for the probes (4 cases of dimensional ranges specific for industrial probes, 4 cases of dimensional ranges specific for optical probes and 2 cases dimensional ranges specific for probes used for biomechanics). The set of two text-boxes for the scanning parameters have each one 4 cases: the first one means 4 situations (5, 10, 15 or 20 scanning points per vector) and the second means 4 cases (scanning by 2, 5, 7 or 10 vectors).

In blue there are represented the output variables meaning the scanning process results, as follows: the parameters defining the scanning area (scanning distances along both axes) and scanning increment along both axes. Besides the displayed results on scanning point coordinates for the 3 axes, a numeric indicator informs the user about the dimensional tolerance of the probe (Figure 5). The programming algorithm was based on the calculation formula of the dimensional tolerance, according to the actual standards.

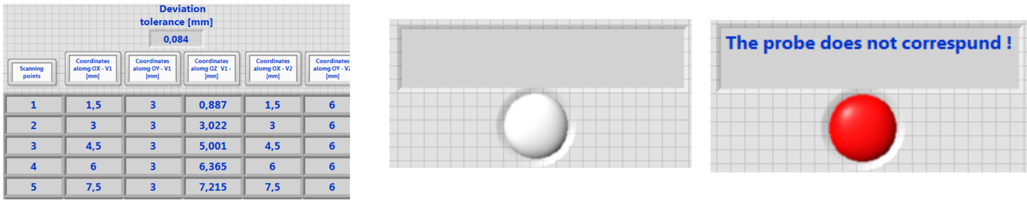

Fig. 5. *Displaying the results on the scanning point coordinates and tolerance value for the current scanned probe, including the LED of state*

Besides, a LED of state together with an optional text message informs the user if the inspected probe correspond dimensional standpoint. If it correspond, the LED is turned off and no one text message in displayed.

At the actual stage, the software application allows post scanning data processing, the procedure of its running being the following: the user has to establish all necessary inspection parameters (probe's application, dimension, scanning parameters etc.), via red text-boxes. If he choose to process the data, during running, he will select, one by one all the .TXT or XLS files containing the primary measured data. Thus means that, previously, during scanning process, the measured values (only along OZ axis) were saved as text or EXCEL files.

4. Results and Conclusion

Using the software application we have tested two sets of probes, providing from all three categories (two radial ball bearing inner rings, for industrial applications, two spherical lenses, for optical applications and two tibia prostheses, for biomechanics).

In case of bearing inner rings, these have been selected to be in the 3rd dimensional class (about 35 mm in diameter and 16 mm thickness), being scanned in 5 vectors, each one containing 10 measuring points. The first and the last scanning vectors were disposed outside of the raceway and the other three vectors were considered inside the raceway. It was proved that both inner rings corresponded standpoint form deviations.

In case of spherical lens these have been selected to be in the 4th dimensional class (about 45 mm in diameter), being scanned in 5 vectors each one containing 10 measuring points. It was observed that for the first lens the measured spherical deviations were inside the imposed tolerance field (reported to the dimensional class), meaning that it corresponded. For the second lens the total spherical deviations were higher than the imposed tolerance field meaning that it did not corresponded.

Referring to tibia prostheses, the first one have 125 mm length, 18 mm width and 1.5 mm thickness, corresponding to adult's prosthesis, and the second have 80 x 12 x 1.2 mm, corresponding to children's prosthesis. Each one has been scanned following 5 vectors, 10 points each one. It was observed that no one of the inspected prostheses did not corresponded form deviation standpoint.

In terms of precision level, all components were inspected using as measuring device a displacement incremental transducer, with 0.2 μm accuracy, corresponding to a high precision.

The way of components quality testing and results obtaining proved that the software application as virtual interface was very efficient and easy to be used, meaning that it could be successfully used for many other application in all fields.

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