Вісник Тернопільського національного технічного університетуhttps://doi.org/10.33108/visnyk_tntu
Scientific Journal of the Ternopil National Technical University
2021, № 2 (102) https://doi.org/10.33108/visnyk_tntu2021.02
ISSN 2522-4433. Web: ***visnyk.tntu.edu.ua***

UDC 681.2: 004

SOFTWARE OF HIGH-PRECISION GONIOMETRIC COMPLEX WITH ARTIFICIAL INTELLIGENCE

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Summary. *Software of high-precision goniometric complex with artificial intelligence developed by the authors, particularly with artificial neural networks, with advanced functionality, designed for non-contact high-precision measurements at the previous settings of navigation sensing elements, flat angles, pyramidal prisms, other production objects, refraction index of optical glass, etc. is presented in this paper. The proposed software product has advanced capabilities, particularly, allows high-precision analysis of the intensities of the spectral distribution of chemical elements in metal-containing materials. The structure of the software reproduces the paradigm of modular construction, which determines the flexibility, extensibility and variability of software components. As a result, neural network processing of measuring information, automatic filtering by the method of moving average output signal noisy by errors of different nature is implemented.*

Key words: *software, high-precision goniometric complex, artificial neural network, measurements running speed.*

https://doi.org/10.33108/visnyk_tntu2021.02.013 *Received 18.05.2021*

Statement of the problem. The development of science and technology puts forward new increased requirements for the accuracy and speed of instrumentation systems for measuring angles. The problem of improving the accuracy and speed of measurements in mechanical engineering and instrumentation, which can be achieved by developing new and improving existing goniometric systems and systems and the latest software is of great importance. Such solutions can be obtained by solving a number of problems related to the need for further development of information and computer technologies for analysis and processing of rapidly changing, noisy by character and manifestations errors of measurement information, including goniometric complexes and systems operating under unfavorable and non-stationary production conditions of mechanical engineering and instrument making. In this context, the development of the latest software (SW) for high-precision goniometric complex with artificial intelligence (GCAI), capable to operate with rapidly changing and measurement information noisy with errors is an important scientific and technical problem, the solution of which significantly provides the solution of the existing problem.

Analysis of the available investigation results. Analysis of the current state of the world market of measuring complexes and systems indicates that their list is quite significant today, they have different ranges of measurement, accuracy, and running speed, and their software is based on the use of various complex algorithms, mathematical models and methods of measurement data `processing [1, 2]. So two models of Mask R-CNN are used in paper [3] as a software kernel at computer estimation method during goniometric measurements of backbone curvature angle. OpenDrop software with open program code is used in paper [4], but it is not indicate whether the measurement results are evaluated for accuracy. In paper [5] goniometric measurements of the rotation angle of the bridge support is carried out by image processing methods, implemented in the appropriate software. However, the «opacity» of computational operations calls into question the objectivity and adequacy of the obtained results of measuring and evaluating the result accuracy, determining the need of additional investigations.

There is a number of scientific papers that describe approaches to the information analysis and processing, as well as the paradigm of software construction. In particular, in scientific papers [6, 7] aspects of the system approach and computer processing of information on increase of accuracy, speed and quality of processing of surfaces of details of mechanical engineering are developed. In [8] the development and implementation of information-measuring system for the presentation and analysis of information on man-made cycles of an industrial enterprise to provide automated measurements with high accuracy and speed. In [9] approaches to information processing are described, as well as the paradigm of software construction of measuring system designed for rapid spectral analysis of multicomponent processes. Despite the obvious scientific and practical achievements and the obtained real practical results in papers [6–9], the problems of software development for goniometric systems with their own features are not covered.

Thus, it can be argued that an important scientific and technical problem of developing original and modern software for goniometric systems, including GCAI, capable to operate with rapidly changing and error noisy measurement information, as well as to provide high accuracy and running speed that corresponds to real time, where information processing is carried out at the speed of events has not been solved.

The objective of the paper is to develop software for improvement the accuracy and running speed of measurement and GCAI information processing.

Statement of the task. High-precision GCAI built on the basis of intelligent precision goniometric system (IPGS) [1, 2] with artificial intelligence elements, particularly artificial neural networks (ANN) [10] is well-known. The structural scheme of GCAI is shown in Fig. 1.

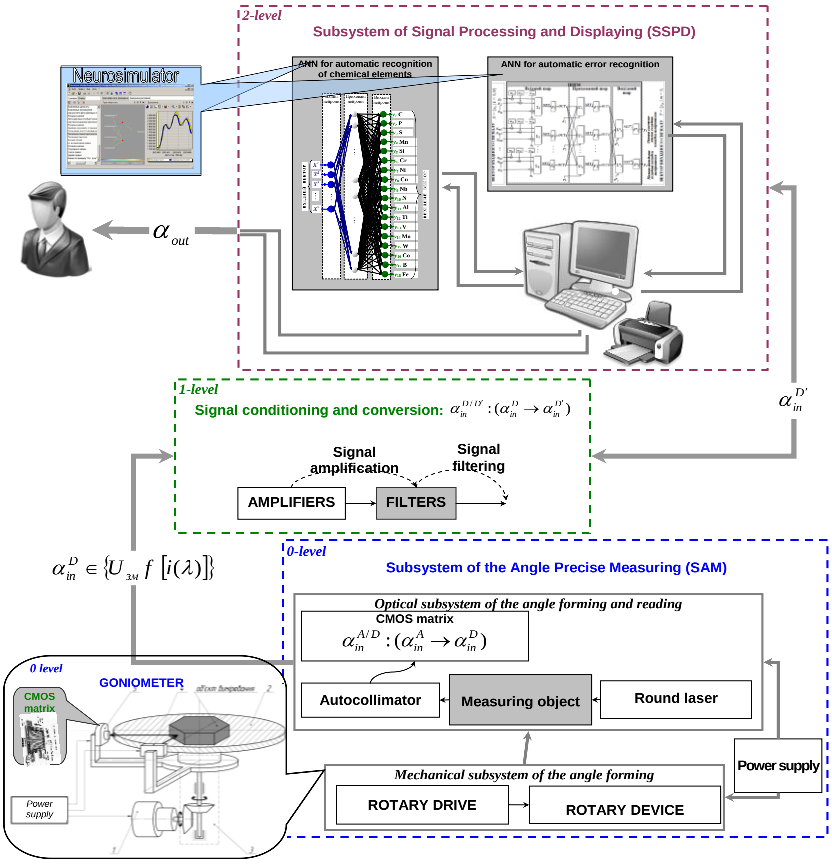

Figure 1. Block diagram of GCAI (source [1, 2])

IPGS particularly is developed using the latest advances in science and technology in the fields of optics, mechanics, electronics, automation, artificial intelligence, and combines advantages such as accuracy and measurement running speed, ease of use, versatility, the ability of automated processing of measurement data in real time. GCAI can be used for non-contact high-precision measurements at the previous settings of navigation sensitive elements, flat angles, pyramidal prisms, and other production objects, the refractive index of optical glass [1], in addition has advanced functionality in analyzing the intensities of spectral distribution of chemical elements during the determination of chemical composition of metal-containing materials [2, 10]. The main basic component of GCAI is the well-known GC1L, which is developed by SE «Arsenal» with active participation of the Instrument – Making Department of NTUU «Igor Sikorsky Kyiv Politechnic Institute».

GCAI is built on the principles of synergetic integration, emergence, invariance, hierarchy, automation, aggregation, etc. It is a functional set of different technical means with heterogeneous properties. The main new elements that have been separated and additionally introduced are the photosensitive matrix on the complementary metal-oxide-semiconductor structures (CMOS-matrix), ANN and filtration subsystem based on the Kalman filter.

Synergetic integration of new elements in GSAI composition makes it possible to apply new methods of measurement data processing, for which the need of program implementation in relevant software to ensure GSAI functioning is obvious. Moreover, one of the main requirements for GSAI software should be its performance on personal computers (PCs) with different resources under conditions of limited RAM and low computing power. Despite the achievements and practical results, it is necessary to implement the possibilities of information processing by neural network methods and the output signal filtering from noise caused by different in nature and manifestation errors of measurement information; to provide flexibility, extensibility and variability of software components, which is the task of this paper.

Description of high-precision GCAI software. Taking into account the problems, objectives and set tasks for software development, it is necessary to use the principle of modular construction, which meets the above mentioned requirements. The software structure is based on the multilevel organization of computational processes (Fig. 2).

In general, the software is implemented on modular basis and is a set of applications combining a number of software modules developed by the authors in MATLAB programming language, which is an add-on of the eponymous mathematical modeling environment, as well as a set of ready-made applications providing ANN operation for rapid and accurate data processing. In particular, the capabilities of the analytical package Deductor Professional which contains neuromodulator Neural Analyzer, designed to operate with ANN and MS Excel spreadsheet are used.

The above mentioned makes it possible to make the software functionally flexible, to control the process of measurement, data entry and visualization of results in graphical and tabular form.

The graphical interface of the user software enables to work in two modes: the mode of angles measuring and the mode of spectral analysis. The measurement process is controlled both manually and automatically. In particular, in manual mode, the operator sets such parameters as accuracy of statistical sample and value of the confidence probability. The required number of measurements can be set both manually and calculated automatically by Fisher's test.

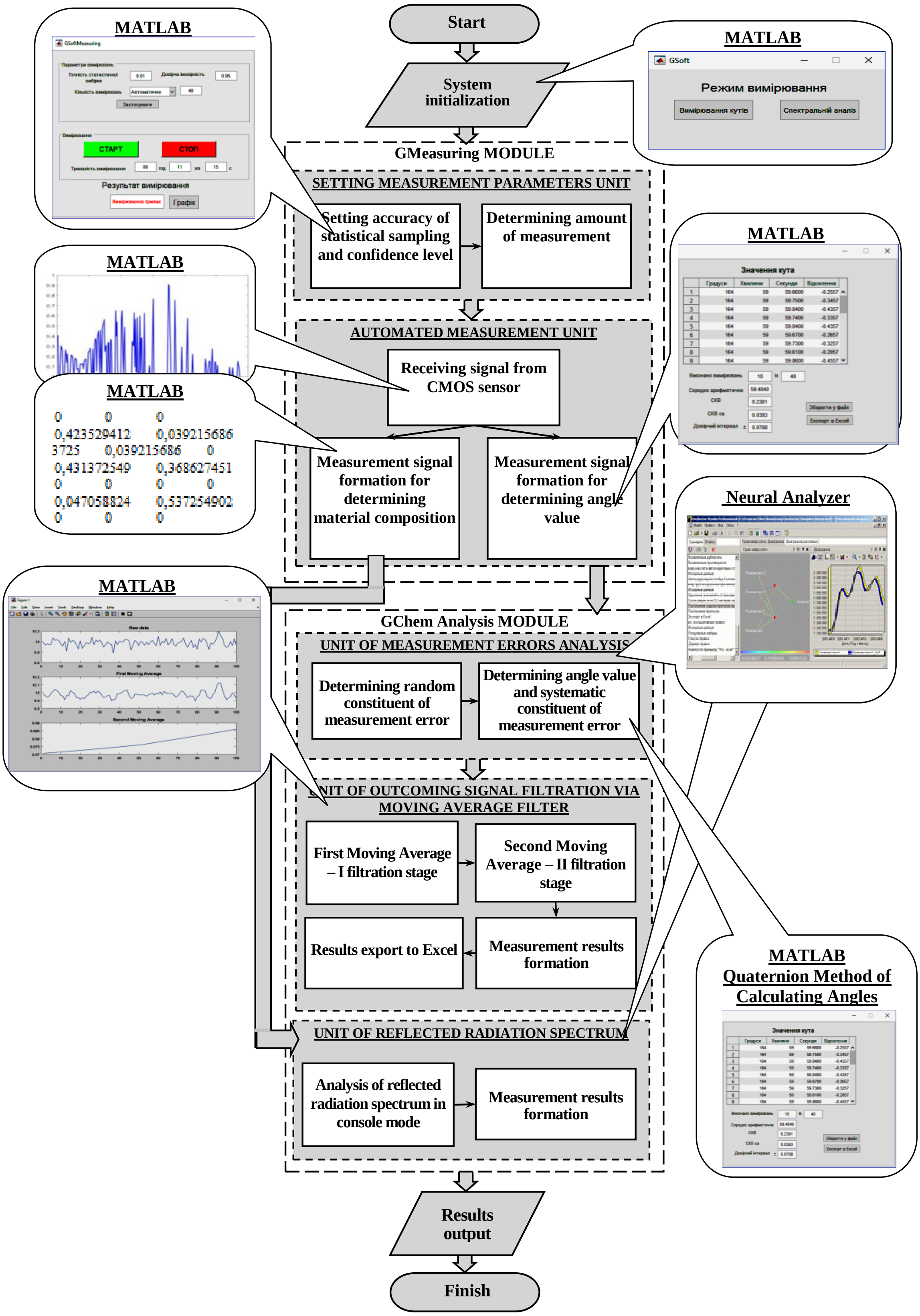

Figure 2. Block diagram of GCAI software operation (source – author's development)

Graphical intuitive interface of the developed software, which windows indicate its functionality is shown if Fig. 3.

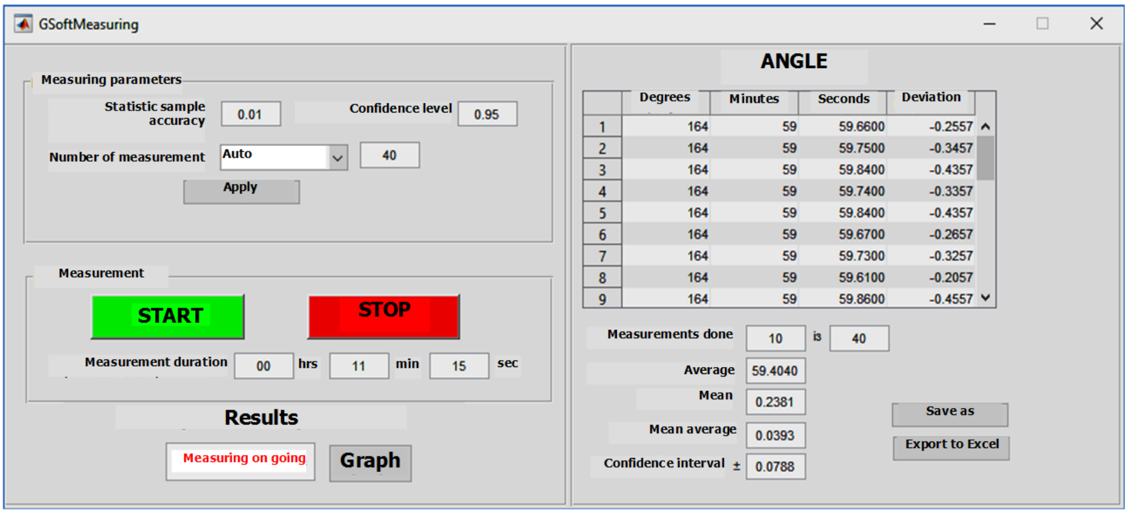

Figure 3. Dialogue box of GMeasuring module of the developed software for GCAI functioning (source – author's development)

After setting the measurement parameters, activation of GCAI hardware and data transmission channels by pressing button «START» by the operator, the measurement time is fixed and continuous data analysis is in the on-line mode. The obtained measurement results are automatically entered in the table «Angle values» in the following format: angular degrees, minutes, seconds and deviations in angular seconds. Visualization of changes in measurement results is carried out in graphical form (Fig. 4).

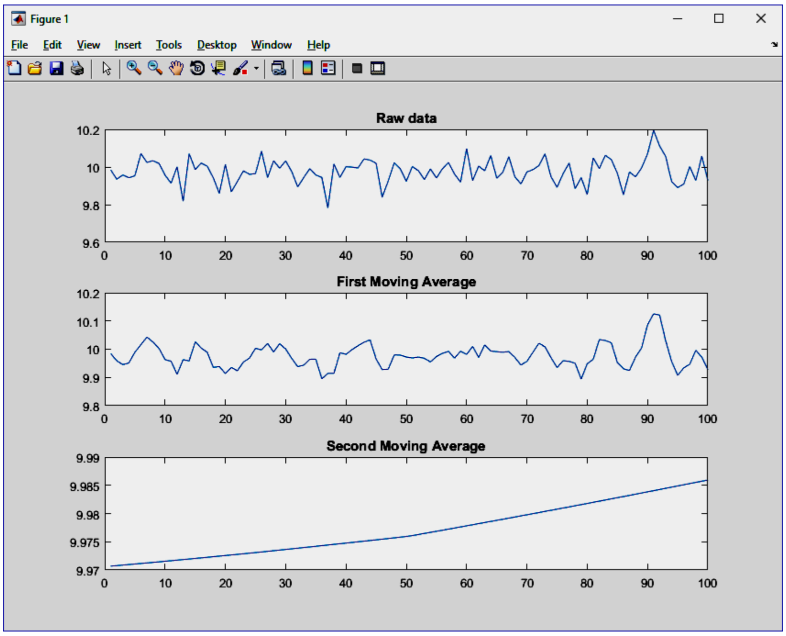

Figure 4. Visualization of measurement results while measuring the angle of 10° (source – author's development)

Graphs in Fig. 4 show the process of changing the measurement results in time (Raw data), the result of filtering error noisy measurement data in the first (First Moving Average) and second (Second Moving Average) stages by Kalman filter implemented by its individual case by the moving average method.

The results are stored when the operator presses «Save to file» button. In particular, a dialogue window appears, making it possible to save the results. If you need to exchange data with other software applications of the operating system, the obtained results can be saved in .xls and .xlsx format by pressing «Export to Excel» button.

If it is necessary to analyze the intensities of the spectral distribution of chemical elements, the mode «Spectral analysis» is selected. This launches the GChemAnalisis module. In this case, the signals from CMOS-matrix are fed to ANN, which performs automatic spectral analysis of the radiation of chemical elements of metal-containing materials in the cantilever mode and displays the composition of the analyzed material.

The software maintains its performance on PCs with low hardware requirements, limited RAM and low computing power, such as PCs with the architecture compatible with Intel x86 / 64. In addition, the software can run under control of various operating systems, including MS Windows 9x / NT / 2000 / XP family and more modern, UNIX-like operating systems, including Linux, Solaris, etc., and Mac OS. This emphasizes the flexibility of the developed software. The possibility of extensibility and variability of software components is also provided. The proposed software can be used as an additional toolkit completed with MATLAB or installed separately without this environment.

Experimental investigations of the proposed software during the measurement of the angle of 24-faceted prism for regulating and setting of angular instruments and measuring of industrial products angles confirmed its efficiency and made it possible to perform multiple measurements with high real-time speed and high accuracy at which the measurement error did not exceed 0.08″.

Conclusions. In the framework of improving the accuracy and speed of instrumental systems for measuring angles, the problem of GCAI software development is set up. The latest software has been developed. It automates operation of GCAI, functioning under adverse and non-stationary production conditions. The software provides goniometric measurements with high accuracy and speed, and also supports the implementation of advanced functionality in terms of spectral analysis of the intensities of the spectral distribution of chemical elements while determining the chemical composition of metal-containing materials.

The algorithms and methods of measurement data processing used in software ensure the speed of goniometric measurements in real time, and high accuracy, particularly the error of the final results obtained by multiple measurements does not exceed 0.08″, which meets the world accuracy requirements for modern production.

The proposed software meets the requirements of performance on PCs with different resources, under the conditions of limited RAM and low computing power. So the minimum hardware requirements of PC for comfortable software is the processor – Intel Core2Duo 6300 1.86 GHz, RAM – 2048 Mb, at least 2 Gb of free space on HDD, CD-ROM.

The processing of information by neural network methods and output signal filtering of the from noise caused by errors of various nature and manifestations is implemented.

The chosen paradigm of modular software construction for GCAI provides flexibility, extensibility and variability of software components, which favorably distinguishes the developed software from those known and used today.

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УДК 681.2: 004

ПРОГРАМНЕ ЗАБЕЗПЕЧЕННЯ ВИСОКОТОЧНОГО ГОНІОМЕТРИЧНОГО КОМПЛЕКСУ ЗІ ШТУЧНИМ ІНТЕЛЕКТОМ

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Резюме. *Викладено розроблене авторами програмне забезпечення високоточного гоніометричного комплексу зі штучним інтелектом, зокрема штучними нейронними мережами, з розширеними функціональними можливостями, який призначений для безконтактних високоточних вимірювань при попередньо виставлених навігаційних чутливих елементів, плоских кутів, пірамідальності призм, інших об'єктів виробництва, показника заломлення оптичного скла тощо. Запропонований програмний продукт володіє розширеними можливостями, зокрема дозволяє з високою точністю проводити аналіз інтенсивностей спектрального розподілу хімічних елементів у металовмісних матеріалах. Структура програмного забезпечення відтворює парадигму модульної побудови, що зумовлює гнучкість, розширюваність та змінюваність програмних компонентів. У результаті реалізовано нейромережеву обробку вимірювальної інформації, автоматичну фільтрацію за методом ковзного середнього вихідного сигналу зашумленого похибками різної природи. Алгоритми та методи обробки вимірювальної інформації розробленого програмного продукту забезпечують проведення безконтактних гоніометричних вимірювань високоточним гоніометричним комплексом зі штучним інтелектом у масштабі реального часу з похибкою кінцевих результатів при багаторазових вимірюваннях, яка не перевищує 0,08″. Низка програмних модулів програмного забезпечення розроблена мовою програмування MATLAB, що дозволяє використовувати його в якості додаткового інструментарію в комплекті з однойменним середовищем математичного моделювання, або інсталювати окремо без нього. Програмний продукт ефективно працює на персональних комп'ютерах з різними ресурсами, в умовах обмеженої оперативної пам'яті та малої обчислювальної потужності. Обрана парадигма його модульної побудови забезпечує гнучкість, розширюваність та змінюваність програмних компонентів, що вигідно відрізняє розроблене програмне забезпечення від відомих та використовуваних нині.*

Ключові слова*:програмне забезпечення, високоточний гоніометричний комплекс, штучна нейронна мережа, швидкодія вимірювань.*

https://doi.org/10.33108/visnyk_tntu2021.02.013 *Отримано 18.05.2021*