Concept of robotic investigational study

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Abstract. The approach as a concept for automated experimental research conducting under management of a controller and a research program control system is stated in the article. Method of robotic tools using to perform experiments with the replacement of the investigated objects without researcher participation is considered in a concept. Variant for automatic revision of the experiment schedule based on preliminary measurements and their evaluation, including analysis of preliminary results using criteria for accuracy and validity of expected results has been considered. The essence of the concept is shown and implementation examples of the concept have been resented upon automation of experimental research. Advantages and prospects of the proposed approach are shown, in particular the authors believe that experimental studies robotization will enable to evaluate and improve the accuracy and validity of the research results; as well as concept is useful for many types and directions of experimental investigations as aimed at human and economic costs reducing, research tasks solution acceleration.

1.Introduction

The methodological, scientific and educational literature contains numerous recommendations for organizing, planning and conducting of investigational studies, for example [1,2,3,4]. There are also publications devoted to the robotization of investigational studies, for example [5]. We have made an attempt to discover the concept of robotic investigations based on our own experience in organizing and conducting of investigational studies [6] as well as taking into account the capabilities of modern microprocessor technology and programming upon investigational studies conducting [7,8].

Let's consider the role and implications of investigational studies for new machines and new technologies creation. At the same time, we will not focus on the methods of experimental research, on the features of the used converters, sensors, measuring equipment; on the methods of the experiments results processing [9]. Every machine, technology is constantly being improved. There is a worldwide practice of advanced technologies and advanced equipment creating. This is a triad in any scientific and technical direction: investigation, design and construction, production and testing of an experimental sample or new technology testing.

It is impossible to create modern technologies, machines, and equipment with separate ideas, without specified triad. Herewith, continuous research and development (R&D) are mandatory as far
as machines and technologies are constantly being improved [10]. And slogans which use the concepts: "innovation theory", "innovative", "breakthrough solutions", "import substitution" are senseless if they do not include the concepts of "research and technological development" and understanding the importance of their continuous implementation. Therefore, it is obvious that experimental research improving is of a very urgent task [11].

Scientific knowledge is mainly based on theoretical and experimental research. To solve applied problems and to achieve a goal in any knowledge, the ratio of time and intellectual costs for these types of research may be different. It is obvious that subject matter content, the specifics of scientific research direction, and even the conclusions on literary and theoretical analyses affect this correlation. It is used more theoretical research during solving some problems, while experimental research is used during solving other problems.

The results of individual stages, both in theoretical and experimental research methods, may lead to the need to correct the overall plan of cognition, the goals and objectives of theoretical and or experimental investigations. That is, the initial goals and objectives of the research are not dogmas, and they can be corrected, supplemented, reduced or changed in the process of research conducting. Sometimes there are errors in the direction of research, sometimes there is a need to clarify significantly the research design. The above approach is the basis of the robotic experimental investigation concept described below.

2. Concept development

As it is known, an experimental research method is used when studying mechanic and technological processes, when studying the composition and properties of various materials in various scientific and practical tasks. Herewith, certain measuring sensors, secondary devices, means of converting and registration for measured values are used. It is also known that most measuring and recording systems have limited accuracy, validity and stability when experimental conditions are changing.

Therefore, the number of experiments, including the number of the influencing parameter variations, can be variable as the results of intermediate experimental experiments are obtained [12]. Otherwise: during experimental studies conducting, based on the results of previously obtained data, it may be necessary to change or adjust the research schedule and objectives.

Each study, experiment, or group of experiments has a specific research schedule. Frequently it is described in detail in various sources, for example [13,14]. Often, a particular mechanic or technological process, or material under study, has certain features which affect the content and sequence of investigation.

Several typical universal tasks of experimental research can be distinguished in order to move on to the concept of robotic investigational studies:
- investigation of previously unknown process, material, construction or method, issues difficult to study from the theoretical perspective;
- verification or confirmation of theoretical research, their test for adequacy;
- clarification of coefficients or other parameters of the object under investigations for theoretical research;
- identification of the validity area, confidence limits of the process theoretical interpretation,
- economic viability establishing for in-depth research conducting, both theoretical and experimental
- hypothesis testing.

It is permissible to specify many options for investigational study tasks, as they are often highly specialized and do not have to be universal.

It is most effective to conduct investigational study through the use of specialized benches, specialized equipment; in premises where stable research conditions are provided, it is possible to vary the parameters and conditions of research. Traditionally, a researcher and/or operator is involved in the process of experiments performing. His main functions are as follows:
- preparation and adjustment of sensors and measuring equipment,
- planning of experiments arrangement, their quantity, range and variation step, modes under study;
- stable conditions ensuring during the experiments conducting;
- test samples replacement or test conditions change;
- control and adjustment of experimental conditions;
- planned change (setting) of conditions of a separate experiment and group of experiments;
- preliminary analysis of the separate experiments results;
- revision of the research schedule based on the results of preliminary measurements,
- adjustment of the required number of single-type experiments;
- monitoring of recording measurement results process;
- other function.

For example, in general view, as a result of experiments, a zone of critical changes in the process indicator was detected. Figure 1 shows a section of such a zone based on the dependence of the oscillation amplitude on the system's stiffness. This is a section of 40-60 microns/N.

![Figure 1](image1.png)

**Figure 1.** Experimental data on the dependence of the oscillation amplitude (A) on the damping device stiffness, for the varying the stiffness step of -10 microns/N.

![Figure 2](image2.png)

**Figure 2.** Experimental data on the dependence of the amplitude on the damping device stiffness, in critical zone, for stiffness varying step of -2.5 microns/N (thin lines).
Often, research does not require a simplified plan of investigational study, for example, a one-factor experiment or research on schemes of Latin or Greek-Latin squares, but a full factorial experiment. Sometimes, in the critical zone of the process under study, it is necessary to adjust or reduce the range for variation of the values of the parameter (factor) under study to clarify the boundaries of the critical zone.

The experiments were supplemented with a study of the critical zone with a step of 2.5 microns/N to clarify the dependence in this zone. As can be seen in Fig. 2, a more precise studied dependence is received.

The revisions to the research schedule based on the results of the analysis of preliminary experiments are effective.

Traditionally, these and other research conditions require operator involvement and more careful planning of experimental studies. At the same time, sometimes it is necessary to repeat experiments, clarify theoretical issues, or change completely or partially the research design. Usually, the researcher realizes the refinement of the experiment layout.

3. Essence of concept

It is proposed to make revisions, repeat experiments, clarify the dependence in critical zones, perform long-term experiments, perform a large number of single-type experiments in which it is necessary to change one or more of the studied parameters; perform experiments in which to change a set of experimental conditions on a scheduled basis - to conduct experiment involving a robotic system for research.

We propose to automate the process of experiments conducting in such a way that a number of the operator - researcher functions are performed automatically managed by control unit in autonomous mode. However, it is not the operator who will vary the modes and parameters under study, but the research program embedded in the programmable controller.

The research program and executive mechanisms will ensure the stability of the experimental conditions, and the variation of the studied parameters, change of the separate experiments conditions. The inclusion of manipulators in the robotic system will allow changing of the samples under investigation, travel devices or objects of research.

4. Concept implementation examples

Let's consider the implementation of this experimental research method as illustrated by the acoustic flat panels study. The influence of the thickness and other dimensions of flat acoustic partitions, material and construction of these partitions, frequency and intensity of sound sources must be studied in identical conditions.

A robotic system for experiments conducting requires a program to control all components of the experiment, including the ability to change sound frequency and intensity, control the recording of data measured by microphones, change the samples under study using either a manipulator or known delivery systems of the circular, revolver or cassette type. We have developed such a bench with the possibility for robotic studies of sound insulation, and experimental work is planned to be realized on the bench.

Another example of robotic experimental research is the organization of investigation on a bench to study the subsystems of small refrigerating machines [15], in particular to study heat and energy indicators of these machines.

The need for robotic experimental studies of these machines is derived from the long process of the steady state operation establishing of the refrigeration unit when its operating conditions is changing. These include change of the ambient temperature in a heat-insulated chamber and thermostat settings adjustment. The higher the ambient temperature is, the longer the process of steady state mode achieving is.
The achievement of a steady state in the refrigeration cycle, at different ambient temperatures, and constant monitoring and stabilization of this temperature is performed in robotic experimental studies of these machines under the control of a programmable controller.

When robotizing experimental research, it is easier to conduct relatively long experiments in stable conditions, and the influence of the "human factor" is excluded. Experimental studies are realized more efficiently, in a wide range of variables diversity, with simultaneous evaluation of the results and plan revision for the experimental investigations.

Figure 3 shows a diagram of a robotic bench for autonomous experimental studies conducting for a refrigerating machine in a heat-insulated chamber.

Experimental investigations are planned to be performed at different air temperatures in the chamber 1. The following are used to change the temperature in the chamber 1 and maintain it at a stable level: a conditioner 4, heat generators 5, temperature sensors 6, and program temperature change unit in the chamber 13.

Figure 3. Scheme of bench for robotic experimental investigations: 1- insulated chamber, 2 - support, 3 - refrigerator, 4 - conditioner, 5 - heat generators, 6 - temperature sensors, 7- sensors on the condenser, 8 - condenser, 9 - sensors in cooling chambers, 10 - power consumption sensor, 11 - measurement planning unit, 12 - temperature control unit, investigation process control block 13.

On a scheduled basis of experiment, operation measurement of the refrigeration unit are realized at a stable, steady-state temperature in the chamber 1, at several levels and steady operation of the refrigerating unit.
Instructions for switching from one temperature level to another are executed by means of the investigation process control block (controller) 13, according to the measurement schedule. The measurement unit 12 and the investigation process control block 13 are used to measure and record the test items. Full details about the design of the investigative bench and its operation are described in research [15].

Robotic investigation studies suggest the preparatory operations performing. The refrigerator unit is placed into a heat-insulated chamber on a support raised above the floor level to a normalized level, according to the standard; temperature sensors, pressure sensors, power consumption sensors are placed in the chambers and subsystems of the refrigerator unit under study.

Quantity, sensors type and their locations are determined by the investigation tasks before measurements starting.

In robotic investigational studies, the main and intermediate measurement results are recorded in the controller's memory and can be accessed online, remotely. Thus, in robotic investigational studies, the research program is performed automatically without operator participation. The software can process the measurement results at any stage of the investigation and can make revisions to the investigation schedule. This involves additional measurements performing, for example, to improve the results accuracy.

The developed and discussed concept can significantly simplify, reduce the cost, and improve the quality of investigational study in the future. The use of Student’s, Fischer’s and other criteria for robotic investigational studies will allow to conduct the autonomous investigational studies with the specified accuracy and validity, taking into account the minimum cost of experimental work, and promptly correct the quantity of single-type measurements.

The developed method can be implemented in investigational studies of materials, parts, constructions, operating modes and process indicators.

5. Conclusions
1. The developed concept of robotic investigational studies increase opportunities of the researcher at the stages of experiments planning and conducting;
2. Robotization of investigational studies will allow evaluating and improving of the investigational results accuracy and validity;
3. The concept is useful for many types and directions of investigational studies;
4. The concept is intended to reduce human and economic costs, to accelerate the research tasks solution.

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