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ALGORITHM FOR CONSTRUCTION AND OPERATION OF SOLVERS IN DECISION SUPPORT SYSTEMS BASED ON THE GROUP METHOD OF DATA HANDLING

The article presents the results of the analysis of decision support system automation tools based on interactive models of the GMDH – Group Method of Data Handling. The organization of the construction and functioning of GMDH solvers in the decision support system at the stages of verification (monitoring of information state) and validation (diagnostics) of decision-making situations is considered. The authors highlight the general algorithm for automatic selection of the best predictors and model structure by minimizing the forecast error. The projected increase in the efficiency of the decision support system due to solvers built on the basis of the GMDH is substantiated.

Keywords: *decision support system, GMDH (Group Method of Data Handling), solvers, algorithm, modeling (model), database.*

Introduction

Statement of the problem. At present, the requirements for the need to make the most effective decisions in planning, designing and managing complex systems are significantly increasing, and often decision-making must occur in real time. Similar situations arise in almost all areas of human activity: political and economic tasks and problems, designing and testing new types of technology, solving environmental problems both on a global and regional scale, managing enterprises and technological processes, etc. The real way to solve emerging problems is to create new information technologies that provide comprehensive support for the process of developing and making decisions, that is, to create a decision support system (DSS). Currently, the development of DSS is carried out, in particular, by integrating artificial intelligence algorithms into such systems, which allows to increase their efficiency. The issue of studying the functioning of DSS based on known and new methods and approaches to solving complex problems and making rational decisions remains relevant. The issue of studying the functioning of decision support systems based on known and new methods and approaches to solving complex problems and developing rational solutions remains relevant.

Analysis of recent research and publications. Automation of decision support processes has led to the emergence of several approaches to building DSS. Such systems are based on the application of modern mathematical methods of decision making, various mathematical models, hardware and software tools. Therefore, the definition of DSS is often associated with these methods, models, tools. Thus, DSS is understood as an interactive computer automated system (software complex), which is designed to assist and support various types of human activity in decision making regarding the solution of poorly structured or unstructured problems. DSS allows users to model and analyze information in a way that is the most effective for developing a specific solution and provides interactive support [1, pp. 20…21].

As for the technology of decision support process itself, the work [2, p. 14] shows the main stages of formation of such a process: verification of information state, validation of decision-making situation, action planning and developing of decisions.

During the decision-making process, the following situations may arise at any stage [2, pp. 14…15]:

structured situation – uniquely defined by the state of data, action plan, assessment of decisions selected by a known mathematical model of decision making;

poorly structured or unstructured situation – for which it is necessary to further determine all or at least one of the components specified above for a structured situation.

In cases where the problem does not have a known algorithmic solution, if the problem area is poorly defined, in conditions of a limited number of observation data, their noise, as well as partial or complete uncertainty about the composition of informative input variables and the structure of the object, there is a need to introduce interactive modeling systems into the DSS, which, as a rule, increase the efficiency of the DSS functioning as a whole.

As a tool for solving problems that arise at the stages of decision making under the above conditions, the most effective is the Group Method of Data Handling (GMDH). In the period 1970-1990s, this method was one of the main tools for modeling complex systems, since it did not require pre-determining the structure of such systems [3, p. 45].

Later, this method evolved, laying the foundations for modern algorithms of automatic modeling. The theoretical foundations of development and practical results of the application of the GMDH are widely presented in many scientific works, in particular [3…14]. And although the GMDH in its modern form has undergone transformation into more powerful tools (neural networks, boosting, ensembles), it is still relevant in modern machine learning (cross-validation, automatic feature selection, multi-level structures), technical diagnostics and forecasting.

Analysis of the specified scientific works devoted to the study of the GMDH allowed us to identify its main advantages, namely:

automatic selection of variables – the GMDH automatically determines the most influential variables and excludes less significant ones, which reduces the dimension of the model and simplifies its interpretation. This is especially useful in problems with a large amount of input data, where manual variable selection is laborious;

automation of model building – the algorithm independently generates models, optimizing their structure and parameters, which reduces the need for expert knowledge of modeling. This makes the GMDH accessible to a wide range of users;

adaptability to nonlinear dependencies – the method effectively models nonlinear relationships between variables through the use of high-order polynomials, which allows describing complex systems without the need to pre-specify the type of dependency;

natural mechanism for protecting against overfitting by using an external criterion (testing on an independent subset);

relative simplicity – low-degree polynomials are often enough to obtain an adequate model;

resistance to "noise" – since the algorithm iteratively selects models with minimal error, it reduces the impact of random deviations in the data ("noise");

versatility – the GMDH is used in various fields, such as economics, medicine, ecology and engineering, due to the versatility of the algorithm. For example, it is used to forecast economic indicators or diagnose technical systems.

Therefore, it should be noted that it is advisable for DSS to use the GMDH due to its ability to automatically create adaptive and stable models for analyzing complex nonlinear data with minimal involvement of experts, which minimizes the negative impact of the subjective factor.

The purpose of the article is to present the results of the analysis of the organization of construction and functioning of solvers based on the GMDH in the DSS.

Presentation of main material

The GMDH is an iterative algorithm for building regression models, which is used in decision making theory to model complex systems and select optimal alternatives. The GMDH is a family of inductive algorithms for mathematical modeling of multiparameter data. The method is based on recursive selection of models, on the basis of which more complex models are built [8, pp. 67…68].

The main idea of the method is the automatic selection of the best predictors and model structure by minimizing the forecast error.

The input data of the algorithm is the characteristic vector $\{x_i, y_i\}, i = 1, ..., n$, where $x_i = (x_{i1}, x_{i2}, ..., x_{im})$ – vector of arguments (predictors) for the i-th object; y_i – objective function (result, evaluation criterion); n – number of objects being evaluated; m – number of predictors of the i-th object.

At each iteration step, partial models are built, usually in the form of second-order polynomials:

$$y = a_0 + a_1 x_i + a_2 x_j + a_3 x_i x_j + a_4 x_i^2 + a_5 x_j^2, \quad (1)$$

where x_i, x_j – pairs of predictors (variables), $a_0, ..., a_5$ – polynomial coefficients, which are estimated by the least squares method.

Models are evaluated by an external validation criterion, for example, the mean squared error on the test sample:

$$E = \frac{1}{n_t} \sum_{i=1}^{n_t} (y_i - \hat{y}_i)^2, \quad (2)$$

where n_t – test sample size; $\hat{y}_i$ – predicted value of the objective function.

The iterative process assumes that all possible combinations of pairs of variables are generated at each layer (x_i, x_j).

The best models (with the smallest E) are passed to the next layer as new variables. The process continues until the error stops decreasing or the specified model complexity is reached.

The resulting (final) model is a combination of the best partial models that optimizes the evaluation criterion (objective function).

For a more detailed understanding of the functioning of DSS, Table 1 provides the main requirements for its application at the first two stages of the decision-making technology.

The GMDH is widely used to evaluate alternatives (e.g., different technical systems) based on several indicators (e.g., technical level, cost, reliability, etc.) by building a model that predicts the integral assessment of the system.

Table 1

General requirements for a decision support system

Requirements	Description
Sources of information	generalized external information, internal database information in the subject area
Precision	robust, regulated
How to present data and modeling results	interface, summary, graphs, charts, interactive whiteboard
Conditions that trigger system activation	signal information, on request, periodic
Forecast time, model class	short-term, medium-term, long-term; static and dynamic models, linear and nonlinear, polynomial, difference, systemic models
Purpose of use	forecasting, recovery, interpolation, extrapolation of database elements: diagnostics of dynamic situations (problem structuring)
Users	database, situational knowledge base, decision-makers, experts: systems for action planning, formation of alternative actions, knowledge base management in actions

Source: developed by the authors

The application of this method in interactive solvers or modeling systems is advisable at the stages of verification, validation of situations of decisions made as well as decision development.

At the verification stage, when the corresponding system cannot, for some reason, identify the state of the database, a system for diagnosing, classifying and predicting the information state is required.

The system of diagnostics and data forecasting, using the GMDH, diagnoses and forecasts the state of the database in the specific subject area. The system performs interpolation (restoration) and extrapolation of both individual components and systemically interconnected database elements. As a result, the database is supplemented with clarified, omitted, or missing data, which is input information for the following stages. Finally, the operation of the data diagnostics and forecasting system leads the database can be filled with both numerical and logical dependencies.

The structural and logical diagram of the system of data diagnostics, classification and forecasting at the stage of verification of decision-making situations is shown in Fig. 1.

The system should work both automatically in case of data inconsistency and on request. Inclusion of the modeling system based on the GMDH in the verification stage allows to significantly expand the capabilities of dynamic databases, as well as spreadsheets due to the synthesis of a wider class of models than, for example, in [11]. The modeling process consists of the stages of problem preparation, problem formulation, solution and evaluation of results.

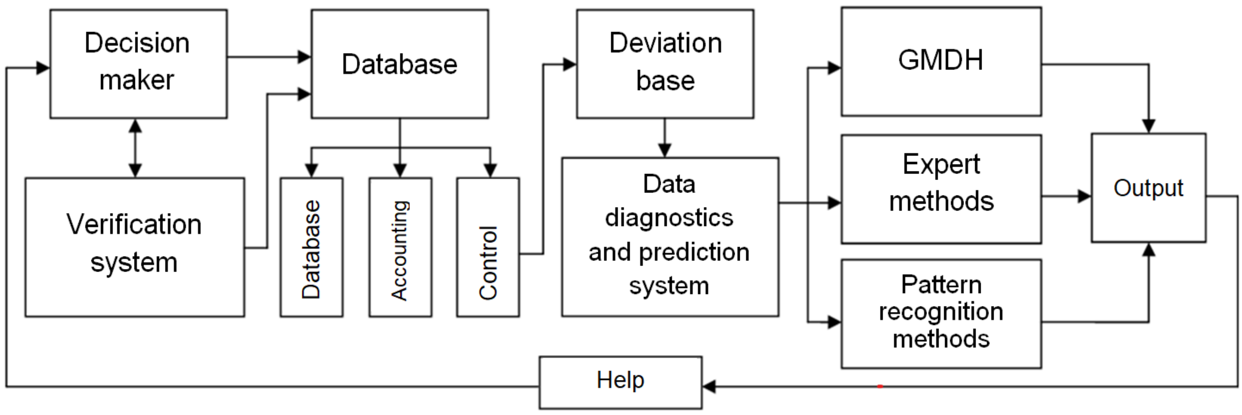

Fig. 1. Structural and logical diagram of the system for diagnostics, classification and forecasting data at the stage of verification of decision-making situations

Source: developed by the authors

At the stage of problem preparation, a statistical analysis of data that comes from the database to the subject area is performed. Based on this analysis, the type of modeling object is determined (statistical, dynamic object or time series) and the class of models is selected.

For static objects, models can be linear (polynomial) or nonlinear (multiplicative-additive). For time series – linear, polynomial, trigonometric, autoregressive (one- and multidimensional), multilevel models of cyclical processes. For dynamic objects – autoregressive models, autoregressive – moving average, linear difference models, multiplicative-additive (nonlinear) difference models, multilevel dynamic models.

The stage of problem formulation begins from the selection of a modeling algorithm (combinatorial, iterative, relaxation), which, like the selection of a model class, can be carried out automatically, at the request of the decision-maker (DM) or an expert. Considering the statistical characteristics of the data, appropriate criteria for assessing the quality of synthesized models or their convolutions are determined for this problem and operating modes are set.

At the stage of problem solving, the system should have a dialogue mode to explain the progress of the problem solving, save intermediate results, and allow active involvement in the process in order to change the course of problem solving at any time at the request of the DM with saving of previous results.

The modeling process ends with the analysis of the obtained models and documentation of the results in a certain form with their subsequent transfer to the appropriate DSS.

At the stage of decision-making validation, the modeling system performs in automatic or automated mode the functions of determining, identifying an unrecognized situation in conditions of poorly structured information.

The expansion of the system's capabilities is ensured by the joint use of expert methods and methods of modeling based on experimental data (GMDH), on the basis of which the problem is structuring, which allows successful modeling of static and dynamic objects and processes in conditions of uncertainty of knowledge about the structure and internal relationships of the object.

In the case the knowledge base does not have a passport for some situation (comprehensive description, analysis and visualization of key characteristics of a problematic situation, which is provided in a formalized form to assist the DM), the system, using the aforementioned methods and the principle of non-final solutions, determines a new situation [14, pp. 22…26].

At the same time, the following possibilities for further determining the situation are used:

expert method;

automated using modeling methods based on experimental data or on pattern recognition methods (both classical and using the GMDH);

combined method, which uses the above-mentioned ones in combination.

The structural diagram of the modeling system for validating decision-making situations is shown in Fig. 2.

The inputs for the system are the values and causes of inconsistency obtained in the verification system, or the set of all data of the subject area obtained from the general information service system.

In the event of conditions under which the system of situation and action goal validation cannot diagnose (identify) the current situation, the inclusion of the modeling system, as well as the diagnostic, classification and forecasting system in the diagnostic process is initiated. In this case, preference is initially given to an automated manner of determination using mathematical modeling methods, on the basis of which the DM, not being an expert, can clearly identify the situation based on the modeling results.

If the DM cannot do this, the work of the modeling system is supplemented by an expert assessment of the situation, and the modeling system can submit a number of obtained models to the expert for evaluation.

The functioning of the modeling system for situation diagnostics is similar to the operation of a such system at the verification stage, which is described in detail above. The class of synthesized models is selected in accordance with the ultimate goal.

The most effective use of such DSS is considered to be in the event of unusual situations, in particular with a limited amount of observations and with minimal or complete lack of knowledge about the object.

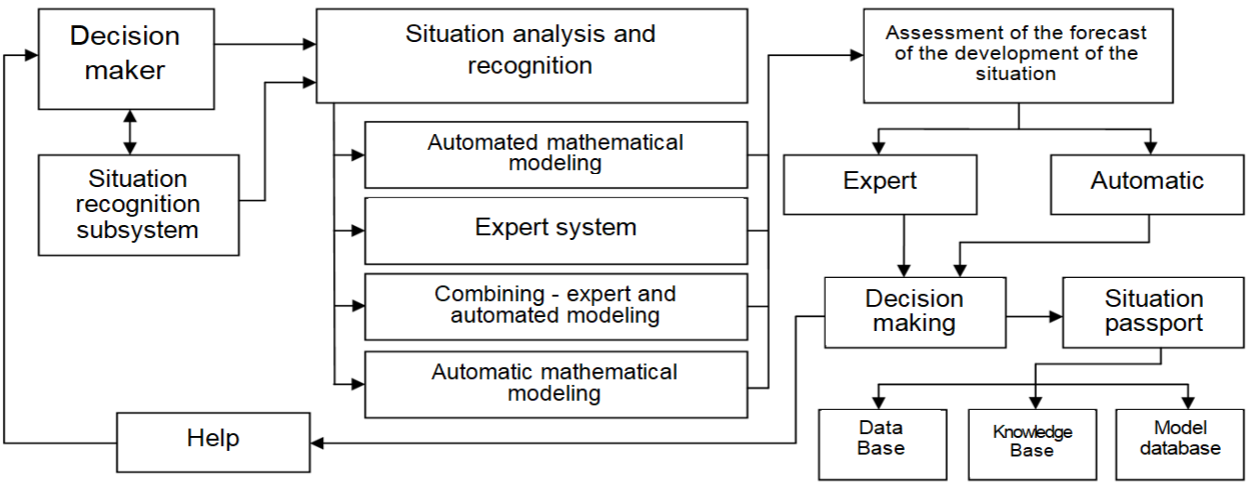

Fig. 2. Structural diagram of a modeling system for validating decision-making situations
Source: developed by the authors

When developing a system, it is necessary to provide for the possibility of its functioning in three modes: automated, semi-automatic, and interactive.

The system software should have the following capabilities:

use of software tools without prior instruction;

clarity and precision of comments and recommendations;

management using modern tools (game design, multi-window interface, etc.);

file work space; return to any previous stage of the system's functioning without loss of information;

use of the system's results as input information for other DSS.

The system is formed as an independent block, which can be used outside the DSS when modeling complex objects and systems based on experimental data. General information about the structure of the system, its functions, control methods, data presentation form, modeling methods used, general and special info about the system should be easily accessible to a user of any level.

It should be noted that depending on the available a priori information about the subject area, statistical characteristics of the data and modeling goals, the system should provide solutions to the following tasks:

restoration of noise-free values of the object's output variables;

building the best model for forecasting (output and input variables);

synthesis of a physical model that reflects the regularity of processes or relationships in the object;

building systemic models – automatic division of variables into input and output as well as restoration of their relationships.

Conclusions

The GMDH remains a relevant tool for DSS due to its automation, adaptability and resistance to "noise", which provides fast and accurate modeling of complex systems. The use of the method reduces dependence on subjective assessments and increases the reliability of DSS in real time.

The obtained accurate and adaptive models can be used both in expert systems and separately at subsequent stages of decision making.

Interactive solvers built on the basis of the GMDH are expected to increase the efficiency of DSS in dynamic situations with a limited amount of observations and with minimal or complete absence of a priori information about the object, ensuring the rapid creation of models that adapt to changes in data, which increases the accuracy of diagnostics and monitoring.

Further research is planned to be directed towards the development of models based on the GMDH in order to assess (forecast) the military-technical level of aircraft, considering current resource indicators.

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АЛГОРИТМ ПОБУДОВИ ТА ФУНКЦІОНУВАННЯ СОЛВЕРІВ У СИСТЕМАХ ПІДТРИМКИ ПРИЙНЯТТЯ РІШЕНЬ НА ОСНОВІ МЕТОДУ ГРУПОВОГО УРАХУВАННЯ АРГУМЕНТІВ

О.Є. Мавренков, С.В. Матвійчук, А.О. Мавренкова, Г.А. Медведєв

У статті представлені результати аналізу інструментів автоматизації системи підтримки прийняття рішень на основі інтерактивних моделей методу групового урахування аргументів. Авторами визначено основні переваги зазначеного методу та доцільність його використання в системах підтримки прийняття рішень з метою автоматичного створення адаптивних та стабільних моделей для аналізу складних нелінійних даних з мінімальним втручанням експертів та мінімізацією негативного впливу суб'єктивного фактора. Показано технологію процесу підтримки прийняття рішень та формування такого процесу на основних етапах – верифікації (моніторингу інформаційного стану) ситуацій прийняття рішень, валідації (діагностики) ситуацій прийняття рішень, планування дій та безпосереднє формування рішень. Розглянуто організацію побудови та функціонування солверів методу групового урахування аргументів в системі підтримки прийняття рішень на етапах верифікації та валідації ситуацій прийняття рішень. На основі результатів аналізу технології процесу підтримки прийняття рішень авторами розроблено структурно-логічні схеми – системи діагностики, класифікації та прогнозування даних на етапі верифікації ситуацій прийняття рішень та системи моделювання для валідації ситуацій прийняття рішень. У статті сформовано загальні вимоги до системи підтримки прийняття рішень та програмного забезпечення системи моделювання. Приведено загальний алгоритм автоматичного вибору найкращих предикторів та структури моделі шляхом мінімізації похибки прогнозування. Обґрунтовано прогнозоване підвищення ефективності системи підтримки рішень завдяки солверам, побудованим на основі методу групового урахування аргументів.

Ключові слова: система підтримки рішень, метод МГУА (метод групового розгляду аргументів), розв'язувачі, алгоритм, моделювання (модель), база даних.