Automated Systems for Information Processing and Control

R. R. Akhmetzyanova, N.V. Andreyanov

***Abstract* — This article discusses the issues of constructing a mathematical model and database of an information system, as well as the organization of the educational process of students in a school robotics club. During the work, the subject area was analyzed and the LEGO Builder system and the Stepik online course platform were considered, their advantages and disadvantages were identified. The formulation and methods for solving mathematical problems are described. The algorithms "Selecting a task by the student's level" and "Maintaining student statistics" are presented in the form of block diagrams. The conceptual and logical design of a relational database is demonstrated. As a result, the forms of the initial menu, training levels, student profile and a table with statistical data of the information system for teaching children robotics are presented. Based on the results of the research and development, the conclusion is made about the relevance of developing systems for teaching children robotics in connection with the widespread use of artificial intelligence.**

***Keywords*— database, mathematical support, information system, information technology, robotics.**

I. Introduction

Additional education is one of the most important components of modern education. Various clubs and activities strengthen children's health, develop additional skills and abilities, and form a general culture [1]. For today's children, additional education is also aimed at vocational guidance, as well as preparing children for the future. There are many courses and schools, both online and in person, for any level of training and areas of interest for children. One of the most popular ones today is programming, engineering and robotics. In today's world, technology plays an increasingly important role, so knowledge of robotics can help children successfully adapt to the demands of the future job market. In-person classes often do not use modern technologies to check and control students' results and to study new material. In robotics and programming classes, paper manuals are used to assemble construction sets, and there is no way to see the results of each student's work depending on their knowledge and skills acquired in class. Therefore, an information system is needed to teach children robotics with the ability to select a task for each student depending on attendance and skills, track students' progress, and automatically generate reports [2]. The introduction of information system (IS) will be aimed at improving the organizational, functional management structure and increasing the efficiency of training through the use of technical means of data processing and more efficient algorithms for solving problems.

The automated information system will allow children to learn the basics of robotics, programming and electronics through interactive lessons and practical tasks, as well as learning theory through games. It will also provide access to various educational resources and games that will help children develop their skills and interest in technology [3].

Thanks to the information system, children will be able to delve deeper into the world of robotics, experiment with various models of robots, create their own projects and participate in competitions. This will help them develop creative thinking, logical thinking, communication and teamwork skills.

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R. R. Akhmetzyanova is with the Kazan National Research Technical University named after A.N. Tupolev-KAI, Kazan, Russian Federation, e-mail: AkhmetzyanovaRaR@yandex.ru).

N. V. Andreyanov is with the Kazan National Research Technical University named after A.N. Tupolev-KAI, Kazan, Russian Federation, e-mail: nvandreyanov@kai.ru).

II. Comparative analysis of systems

A similar automated information system for students in educational institutions called LEGO Builder was developed by Light Brick Studio. It allows you to organize your personal Lego collection, track your progress, have a collaborative building function, and also see online instructions. Users can order parts for their model and build it in reality. LEGO Builder offers a convenient and interactive way to learn LEGO and develop your building and design skills. [4].

The application has many advantages, but there are also a number of disadvantages. In this system, each instruction describes all actions step by step, but in real life this will not happen. Details depicted in real size, but no text, which would explained theory and called parts used a child when assembling a construction set. This simplifies the work, but the names of the parts are not remembered, and students do not they know how to work with diagrams, there is no understanding of how the result is achieved. Besides, in force existing political-economic situation, usage foreign systems are associated with risks blocking, what will affect on ensuring continuity of the educational process. For this reason, it is necessary to create a domestic IS that meets all modern requirements for robotics training systems. This will allow improve user experience and increase system reliability due to its placement in russian servers.

To learn robotics, you can also create a course on the Russian educational platform Stepik, where you can teach children through videos, texts and a variety of tasks with automatic checking and instant feedback [5]. The platform has many advantages, but at the same time there are

disadvantages. The result of the analysis of the systems is presented in table I.

Table I. Result of analysis of systems

Comparison options	Course on Stepik	Robotics	LEGO Builder
Developer	Nikolai Vyakhhi, founder and director of the platform	Domestic development, it is possible to install the system at any time	Light Brick Studio (foreign company), today there is no way to find the application in the public domain
Ability to work without the Internet	It is possible to download video lectures and theoretical material, but completing assignments is impossible without the Internet	Yes, internet is not required	No, you definitely need internet to work
Price	It is possible to create a free course, but without additional functionality (assessment and monitoring of student progress; checking completed assignments; importing grades from files)	Free with additional functionality	For free
Safety	Registration is required to enroll in the course, so data may leak	Unlikely data leakage since the system is deployed locally	Possible data leak
Support	There is technical support	If problems arise with the system, you can contact technical support for help. support	If problems arise, there is no way to solve problems face-to-face
Ability to create interactive lessons	There is no such option	This possibility exists	No possibility to create interactive lessons

Thus, we can conclude that to teach children robotics it is better to use the domestic “Robotics” system, since it is possible to work with the system without the Internet, and in schools there are often problems with access permissions to certain sites and the network, and the system is also more secure , since there is no need to register on the global network, it is possible to scale the system and contact technical support.

And an information system for teaching children robotics will be an important tool that will help prepare the future generation to work in the modern technological world. It will help children expand their horizons and become successful specialists in the field of robotics and programming. To create such an information system, it is necessary to think through the mathematical component, and the problems that will be solved by the system using mathematical methods. This system will solve the following tasks: choice tasks by level student; lead statistics for each student.

V. Mathematical component of information system

When developing mathematical software, a mathematical model is formed that reflects the specifics of the subject area of the information system, and approaches to data processing are determined [6]. The mathematical model is created in a formal language, which allows formal methods to be used to solve various problems. Three main types of problems are distinguished: logical, computational and optimization.

To solve logical problems, models from discrete mathematics are used, including set theory, graphs, mathematical logic and first-order predicates. Computational problems require the development of expressions (formulas) that are used to calculate the parameters of the controlled process. Optimization problems are aimed at finding optimal parameter values in a given range of acceptable values, which contributes to the adoption of effective management decisions based on the selected criteria for the quality of management [6].

VI. Selecting a task by student level

Verbal description of the task. Let available i – tasks and j – students. One task can be completed by one of the students.

R_{ij} – quality execution i-th tasks j-th student. Q_i – difficulty of completing the task.

It is required to distribute all the tasks among the students so that the tasks are not repeated, and so that the difference between the quality of the i-th task performed by the j-th student and the complexity of the task is minimal. To visually describe the problem, table II was compiled, which shows many variable designations.

Table II. Designation variables

Designation	Explanation designations
i	Number task
j	Number student
R_{ij}	Quality execution of the i-th task j-th student
Q_i	Complexity execution tasks
n	Quantity tasks.
m	Quantity students

x_{ij}	Boolean variable (mark about assigning task i to student j), which accepts meaning 1, if i-th exercise done j student and equals 0, if exercise not performed.

Problem formulation. Each student j has an individual task i, which he completed in a certain time and quality R_{ij}. There are the following restrictions:

$$n > m \ \#\ (1)$$

$$\sum_{j=1}^{n} x_{ij} = 1, i = 1, n \ \#\ (2)$$

$$\sum_{i=1}^{n} x_{ij} \leq 1, j = 1, m \ \#(3)$$

$$x_{ij} \in (0,1) \ \#\ (4)$$

Objective function for each student:

$$\sum_{j=1}^{n} |Q_i - R_{ij}| * x_{ij} \rightarrow min \ \#\ (5)$$

The final formulation of the problem will look like this: each student j stores statistics on the quality of assignments, on the basis of which an assignment will be given in the lesson according to formula 5. Based on the number of tasks and the number of students, as well as the quality of the i-th task performed by the j-th student, an individual task is selected for each student. The trace of the method for solving the problem "Selecting a task according to the student's level" is presented in table III, the flow diagram is shown in Fig. 1.

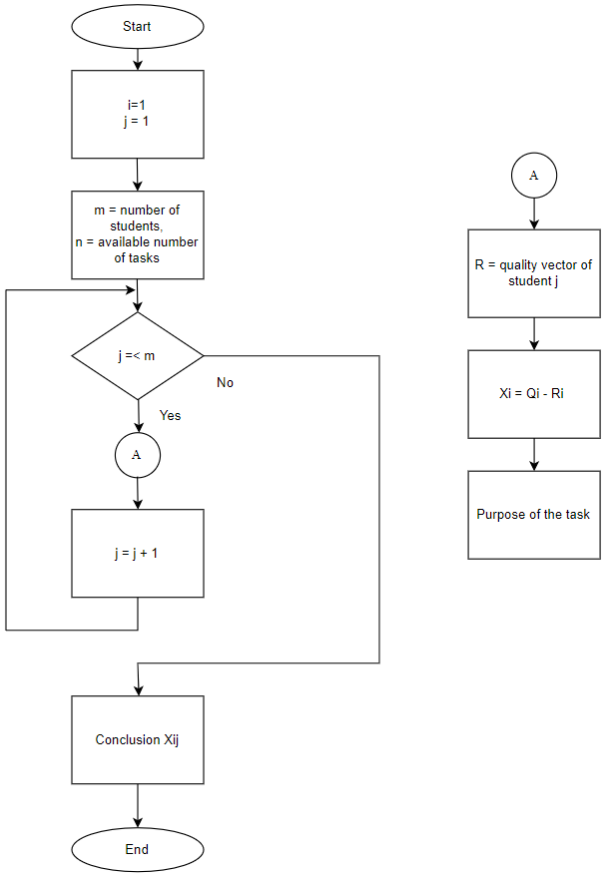

Fig. 1. Flowchart of the method for solving the problem "Selecting a task according to the student's level"

Table III. Tracing the method for solving the selection problem assignments according to student level

Step designation	Step description
Formulation	Given: n, m. Find: X
1	Initialization of variables: $i = 1$, $j = 1$
2	Determining the number of students m and the total number of tasks n
3	Initialization of the quality vector for completing tasks R of student j
4	Find the minimum difference between the complexity of the task and the quality of the task performed by the student
5	Assign task to student j
6	If j != m, go to point 9, else go to point 4
7	Output of generated sample X

XI. THE TASK OF MAINTAINING STUDENT STATISTICS

To solve the problem of maintaining student statistics, an analysis of the task is also carried out and a verbal description of the task is presented at the very beginning: there are many students, for each of whom his time and quality of completing the task are known. It is necessary to determine the R rating, which is the determining factor in the child's learning outcome in the course on assembling a construction set. To solve the problem, table IV is presented, which shows many variable designations.

Table IV. Designation variables

Designation	Explanation designations
n	Quantity tasks
m	Quantity students
i	Number task
j	Number student
K_j	A set of values for the quality of completing a task for a specific student, where j is a specific student. Moreover, $K_i \in \{1..5\}$
Tc_j	A set of time values for completing a task for a specific student, where j is a specific student
Tz_i	A set of values of the time required to complete a task, where i is the task
Tk_j	A set of coefficient values based on the time it takes to complete a task for a specific student, where j is a specific student. In this case, Tk = {-2, 0, 2}. If the student completed the task in less time than defined by the standard, then Tk = 2, if in more time, then Tk = -2, otherwise Tk = 0.
P_j	The set of test result values for a specific student, where j is a specific student. Moreover, $P_i \in \{1..5\}$
R_j	Learning outcome

The formulation of the task for maintaining statistics for each student is as follows: for each student, a grade R_j is determined, based on the quality of completing the task K_j, the time for completing the task Tc_j and the coefficient Tk_j, as well as the test result on the completed task P_j. The formula for determining the R_j rating is as follows:

$$R_j = K_j + P_j + Tk_j, \#\ (6)$$

$K_j = \sum_i^m K_j\ , i = \overline{1,m}$, P_j - number of correct answers in the test, $Tk_j \in \{-2,0,2\}$.

Based on the quality of task completion K_j, task completion time Tc_j and coefficient Tk_j, as well as the test result P_j, student statistics are generated. The trace of the method for solving the problem of maintaining student statistics is presented in table V, the flow diagram is in Fig. 2.

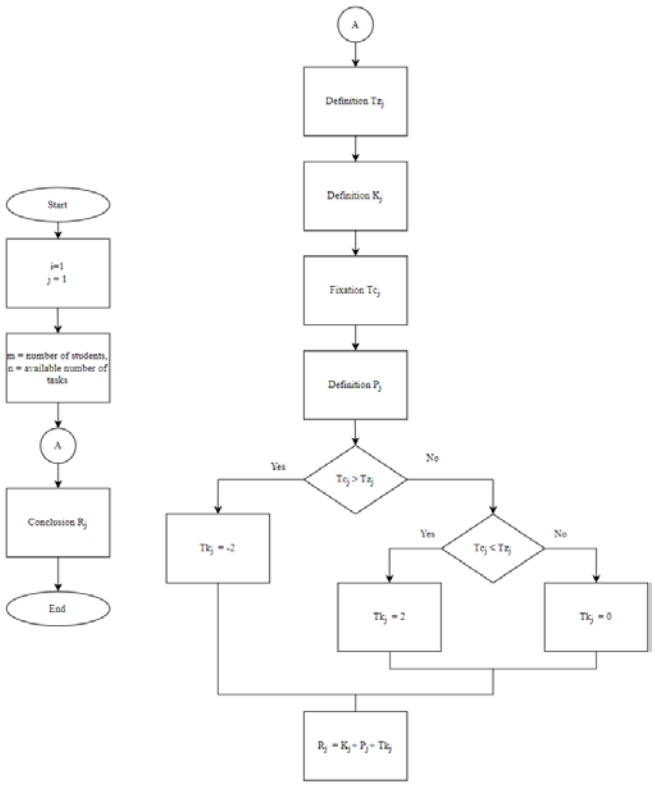

Fig. 2. Flowchart of a method for solving the problem of maintaining student statistics

Table V. Tracing the method for solving the guidance problem student statistics

Step designation	Step description
Formulation of the problem	Given: n, m. Find: R_i
1	Initialization of variables: $i = 1$, $j = 1$
2	Determining the number of students m and the total number of tasks n
3	Initialization of work execution time Tz_i for task i
4	Determining the quality of task performance K_j j by a student
5	Recording the time of completion of the task Tc_j j by the student
6	Determination of test results P_j j of a student by the sum of correct answers
7	If $Tc_j > Tz_j$, then $Tk_j = -2$
8	If $Tc_j < Tz_j$, then $Tk_j = 2$
9	If $Tc_j = Tz_j$, then $Tk_j = 0$
10	Calculation of the sum $R_j = K_j + P_j + Tk_j$
11	Output R_j

XII. CONCEPTUAL DATABASE DESIGN

The conceptual level is transitional from the external level to the internal level. At the conceptual level, it is important to describe the subject area, defining its boundaries and highlighting the objects of the subject area and their characteristics: the data necessary for use in the IS. At this level, the content of the database is presented as a whole, in contrast to the external level, where specific data is provided to a specific user [7].

The main database entities and their properties: the “Pupil” entity contains data about students; the “Exercise” entity contains data about tasks for students; the “Visit log” entity contains data about classes. Entity-attribute relationships are presented in table VI. Attribute descriptions are presented in table VII.

Table VI. Association of entities with attributes

Entity name	Key	Attribute name	Domain name
Pupil	*	Student ID	ID
		Surname and initials	Full name
		Class	Class
		Grade	Grade
Exercise	*	Task of number	Number
		Exercise	Exercise
		Difficulty of the task	Complexity
		Time required to complete the task	Time for task
		Link to theory	Link
Visit log	*	Student ID	ID
	*	Task of number	Number
Visit log		Date of the lesson	Date
		Quality of task execution	Quality
		Student completion time	Student time

		Test result	Test
		Label about solving a task in class	Label

Table VII. Description of attributes

Entity name	Attribute name	Attribute description
Pupil	Student ID	Unique student ID
	Surname and initials	Last name and initials of the student
	Class	Year of schooling and letter indicating class
	Grade	The student's level, determined by the sum of the test result, the time it takes to assemble the constructor, and the quality of execution
Exercise	Task of number	Task ID number
	Exercise	The text of the assignment compiled by the methodologist
	Difficulty of the task	Task level parameter determined by the methodologist
	Time required to complete the task	The time determined by the methodologist required to complete the task
	Link to theory	Link containing theory for completing the task
Visit log	Student ID	Unique student identifier
	Task of number	Task ID number
	Date of the lesson	The date of the lesson when a specific student solved a specific task
	Quality of task execution	Assessment given by the teacher for the build quality of the construction set
	Student completion time	Time recorded by the system when a student completes a task
	Test result	Number of correct answers in the test for the material covered
	Label about solving a task in class	An assignment that was completed in class on a specific date

XVIII. LOGICAL DATABASE DESIGN

The purpose of this stage is to build a logical model focused on the use of a specific database management system [7]. Almost all modern systems support the relational model. The result of constructing a system of complete functional dependencies is presented in table VIII.

Table VIII. Functional dependencies

Entity name	Attribute name	Functional dependencies
Pupil	Student ID	*
	Surname and initials	←
	Class	←
	Grade	←
Exercise	Task of number	*
	Exercise	←
	Difficulty of the task	←
	Time required to complete the task	←
	Link to theory	←
Visit log	Student ID	*
	Task of number	*
	Date of the lesson	←
	Quality of task execution	←
	Student completion time	←
	Test result	←
	Label about solving a task in class	←

The logical model of the database is presented in Fig. 3.

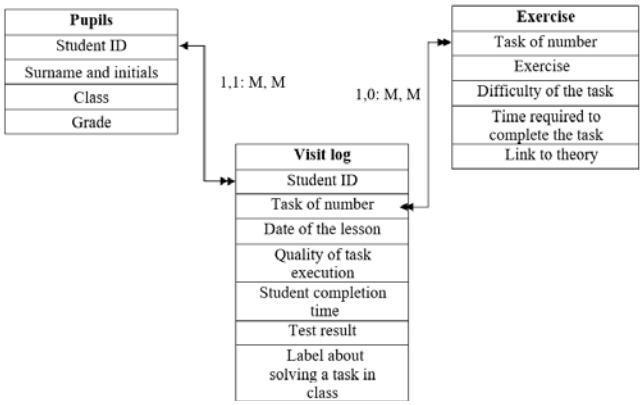

Fig. 3. Logical database model

XIX. INFORMATION SYSTEM INTERFACE

According to the mathematical model and logical model of the database, the Robotics system was developed, which is an information system for teaching children robotics in additional education clubs, which will facilitate the conduct of classes and systematization of students' test results.

To start working with the system, you must go through local registration so that the students' data is saved. After authorization in the system, students have access to tasks and theory. After completing the task, the time is saved and the quality of the work is assessed by the teacher, who gives his grade, after which the students take a test and the first task is considered completed. The data on the first work is saved and

a general grade is given, at the next lesson, depending on this

parameter, the complexity of the assigned work will depend.

Figures 4-8 show the interface of the developed system.

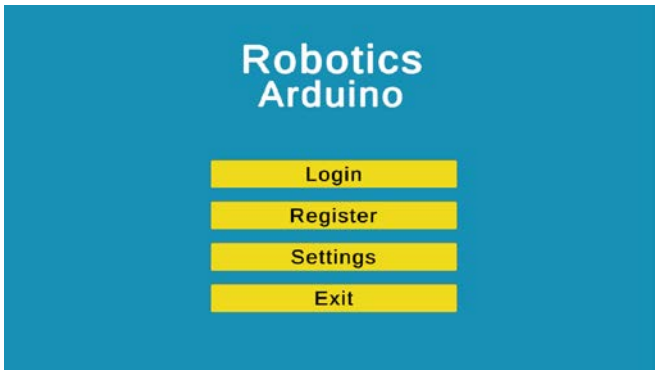

Fig. 4 – Start menu

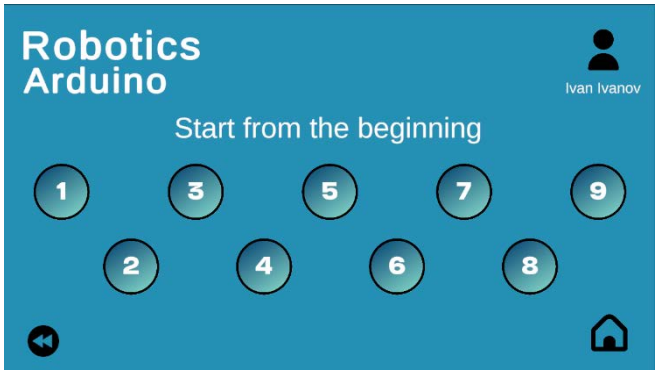

Fig. 5 – Levels window

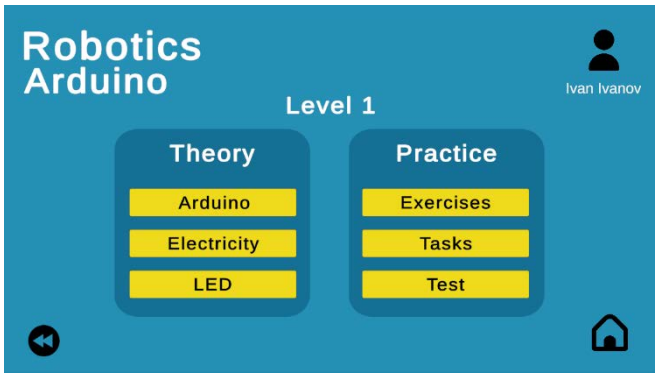

Fig. 6 – First level window

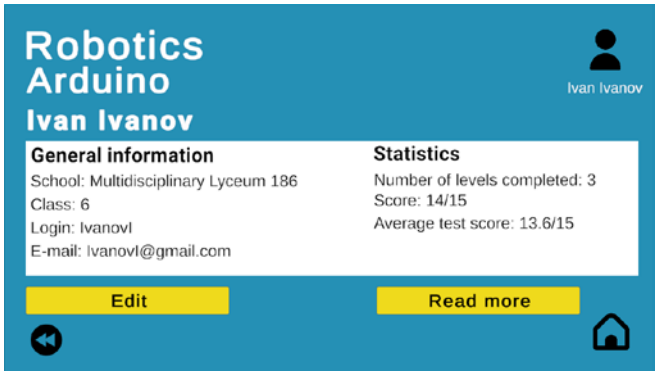

Fig. 7 – Student profile

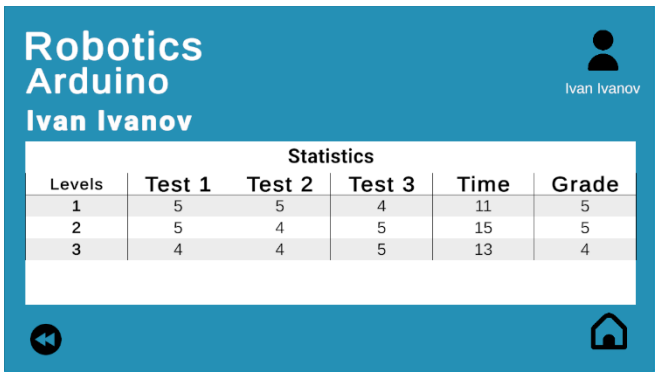

Fig. 8 – Table of learning outcomes

XX. Conclusion

Thus, this article considers the issues of mathematical support and design of IS database to organise the learning process of students of the school circle on the assembly of electronic constructor, and also shows the interface of the system. This system will allow schoolchildren to reduce the time of performing practical tasks; each pupil will be able to choose tasks according to his/her level of problem solving and statistics. This system will facilitate the work of teachers, as the system provides statistics of student's learning.

The article analyses the subject area, considers the formulation, methods of solving mathematical problems of the information system for organising the learning process of students of the school robotics circle. Implementation of IS will allow solving the following tasks: selection of tasks according to the level of students; keeping statistics of students. The paper also demonstrates conceptual and logical design of a relational database.

The information system for teaching children robotics is a convenient and modern solution aimed at improving the educational process.

In the future, it is planned to improve the efficiency of the information system by adding new training modules, improve the system interface and expand the functionality of the information system.

Robotics systems are currently relevant due to the development of artificial intelligence, which allows them to be used in many areas [8-10]. For example, robotic systems can be used in production to identify visual defects in products.

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