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Development of a Reflective Intelligent Project Planning System

Iurii Teslia[a], Ganna Klevanna[a]

[a] *Cherkasy State Technological University, Shevchenko blv., 460, Cherkasy, 18006, Ukraine*

Abstract
Planning is one of the main functions of project teams and one of the most important prerequisites for project success. Despite the development of information systems and technologies, planning methods have remained virtually unchanged, including the critical path method and the PERT method. They are based on the implementation of the opinion of experts on the possibility of performing work in a timely manner, the need for resources, the technological links between the works. It is shown that for the creation and implementation of information systems and project management technologies it is necessary to create methods and tools that will significantly transfer the planning functions to specialized intelligent systems. The problems that should be solved by such systems are formulated. Scientific and methodological approaches to the creation of information systems and planning technologies are analyzed. It is shown that the reflex approach allows to combine and model the influence on decisions in the process of project planning of different physical factors - expert opinions, documentation, information standard of the company, the situation in the project environment. We have utilized a modified reflex method to build an intelligent project planning system. A modified reflex method of developing reactions to the influence of various factors that determine the parameters of the project plan is proposed. The structure of the reflex system of project planning is proposed, which is able to adequately respond and implement decisions on the parameters of project work. The system has passed experimental testing and has shown its effectiveness in the project planning process.

Keywords 1
Project planning, project management software tools, project management information technologies, reflex approach

1. Introduction

Considering that planning is one of the main functions of project teams and one of the most important prerequisites for project success, this process attracts and requires a lot of attention. Today, the work of project management groups on their planning is impossible without the use of such software tools as Oracle Primavera P6, MS Project, Jira, Trello etc. [1-3]. Despite this, planning methods have remained largely unchanged, including CPM and PERT methods. There are two main tasks in the planning process using software tools. Preparation of the Project Schedule Network Diagram (PSND), taking into account the duration of the works, the amount of resources for the works, the connections between the works. And its calculation with the receipt of the project plan. The second problem is solved by instrumental software [1-3]. After all, these and other software tools calculate network graphs, build Gantt charts, distribute resources depending on the time of project implementation, etc. At the same time, they implement technical functions - calculate the network schedule, shift work according to the performance results, calculate the loading of labor resources, etc.

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EMAIL: dr.teslia@gmail.com (Iurii Teslia); h.o.klievanna.asp21@chdtu.edu.ua (Ganna Klevanna)
ORCID: 0000-0002-5185-6947 (Iurii Teslia); 0000-0002-7450-379X (Ganna Klevanna)
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The first task is still solved by managers. Creative tasks related to the preparation of the PSND, in particular, related to the development of the topology of the network model, the distribution of resources, and the determination of the duration of work remain with the project management group. Which places increased demands on the professionalism of managers in the tasks of project planning.

As experience shows, a significant number of projects are not completed in accordance with the work plan. And this is not only due to poor execution of work. But also poor project planning, primarily with poor PSND training. Therefore, the creation of intelligent project planning systems corresponds to these trends and is very modern and urgently needed.

Today, there are no sufficiently effective expert systems that would interact with managers in natural language and solve the tasks of project planning, allocation of resources between works, execution control, and evaluation of the prospects of project implementation in the task of deadlines. Although there is already work in this area to solve local intellectual problems, such as decision support and intelligent data analysis. Thus, the papers [4-5] present the prospects of integrating artificial intelligence technologies into project management. But the works lack the development of intelligent systems for the implementation of the proposed models and methods.

This paper [6] presents an intelligent decision support system in the field of organization of non-profit projects. This system helps determine whether a planned project will be successful by assessing the likelihood of future project success, and provides advice and guidance on how to improve project organization when the probability of project success is low. In work [7]) the information and analytical system of management of the project team in software development is described. This allows you to form effective teams using the Kanban methodology within software development projects.

There are works devoted to the use of expert systems in the management of enterprises and business environments [8]. But their scope of application does not overlap with the tasks of project planning, so it is impossible to apply them in this area.

The analysis of literary sources showed that today there are no functionally complete intellectual systems aimed at the formation of project plans. Who would be able to make effective decisions in the process of forming and calculating project plans, allocating resources between works, and monitoring execution. Therefore, there is an unrealized part of research in the field of creating project management information technologies. This work will be devoted to the issue of creating an intelligent project planning system that would adequately respond to various influences in the project environment and would be able to draw up a project plan that would correspond to the realities of the project.

2. Materials and methods

Our goal of the work is the development of an intelligent project planning system capable of forming the PSND of the project with minimal human involvement. To achieve this goal, it is necessary to the following tasks: to propose a method that would allow to form the PSND of the project efficiently and simply, to develop an intelligent project planning system, and to conduct experimental studies.

The object of research in the work is project planning processes.

The subject of the research is an intelligent system that will take on creative tasks to prepare a project plan - the formation of PSND in terms of links between works, their duration and the necessary resources.

The result of the study should be an intelligent planning tool that allows you to form a CG in the process of verbal interaction with the project team.

2.1. Creative tasks that appear in the process of project planning

In the process of planning projects, the following functions are employed:

1. Molding for the development of the project plan.
2. Selection and analysis of information (documentation, confirmation of the implementation of future projects, minds of the implementers of the project) for the development of the project plan.

3. Formation of PSND.
4. PSND calculation and obtaining a preliminary project plan.
5. Evaluation of the project plan.
6. Agreement and approval of the project plan.
7. Bringing the project plan to completion.

From rescheduling tasks to creative tasks, you can add tasks 1, 2, 3, 4, 5. Let's look at these tasks in more detail:

Task 1. This is decided by the top management of the company and is related to the strategy of its development and business activities and cannot be effectively solved in an intelligent system. Because in the process of solving this, qualitative assessments, confidential information, the attitude of top management and counterparties to the scope of project implementation are often used. But in the future, this task can also be transferred to the digital environment.

Task 2. Applied by the information specialists of the project management group, as well as by the practitioners of the company's functional developments. With the use of two models of project planning (bottom-uphill, top-down), this task can be achieved with a different level of creativity of specialists and practitioners. When planning from the bottom up, specialists and practitioners appoint, as it is necessary to work out (in the area of their competence) and, apparently, pick up documentation for “their expertise”. When planning from top to bottom, specialists and practitioners already take away the preparation of the project and pick up information on the tasks, work is carried out with the method of assigning their parameters (resources commitment, time spent, technological communications with other robots). The task can be solved without human participation only if the digital environment contains all the information about the project: the information standard of the company (which reflects the previous experience of implementing projects), documentation, and an expert assessment of the project and its implementation environment. The development of digital technologies, the creation of methods and means of digital project management will sooner or later lead to the solution of this problem without (or with minimal) human participation.

Task 3. Operate in the automatic creation of PSND based on the knowledge of experts (intellectual systems), information standard, documentation (which determines technological links). As a matter of fact, technological links can be removed not only from the documentation, but also from the advancement of the implementation of the projects and the knowledge of the experts, and the task today can be implemented in the intellectual system.

Moreover, the knowledge of experts is presented through the formalization of qualitative knowledge based on an interview, the essence of which is to obtain answers to the questions posed. For example: What will be the duration of X's work? What resources and in what amount are needed to perform X's work? After which job(s) does job X start and with what delay? If work X starts later than planned, what amounts of resources are needed to reduce its duration by P percent? This information, together with the information generated when solving problem 2, is used to determine the sequence of execution and parameters of project work.

Task 4. It is solved by instrumental project management software.

Task 5. Typically, formal methods are used to evaluate the project plan, in particular, calculations within the project triangle (time, money, quality). These calculations show whether or not the resulting plan will allow the project to be completed within the prescribed time and budget. And whether this time, funds, as well as the planned loading of labor resources is enough to ensure the required level of product quality of the project. In modern project planning systems, this approach is quite productive and of high quality. Its disadvantage is insufficient consideration of the risks of non-performance of the project within the planned funds and time. The use of intelligent systems to solve this problem is possible through the introduction of qualitative assessments of the project plan (reliable, low risk, rational in time and cost, rhythmic, etc.). This problem can be solved in the future by the technologies from which problem 3 will be solved.

Based on the description of these tasks, we can conclude that the creation of an intelligent project planning system with minimal human participation should begin with solving problem 3. Creating a model of work based on expert knowledge, project conditions, documentation and information standards of the company

In addition, it is necessary to assess the input information and the compliance of the task with the capabilities of the project team and its resources. This will be done by displaying the results of solving tasks 1 and 2 in the intelligent project plan evaluation system.

But for its creation, it is necessary to develop a method that will design the topology of the network model and determine the parameters of the projects. Thus the system which will implement this method should:

Receive expert information not only through the knowledge base, but also receive it in dialogue with experts in the process of forming a work plan. To do this, it must be able to communicate with a person on the subject of creating a PSND in a human language.

Take into account information from the information standards. Such information should influence the decision of the intelligent system not only regarding the topology of the network model and parameters of the work, but also about the trustworthy and reliable information from specific experts (how wrong they were in previous projects to assess the parameters of the work).

Take into account the conditions of the project, described in the documentation. This information specifies the data from the information standard by specific (and often new) resources, requirements, limitations. And it is presented both in the human language form, and in drawings, tables, lists, calculations. Therefore, the intelligent system must take into account the impact on the project plan of heterogeneous information describing the conditions of the project.

It is very difficult to create an intelligent system that would be able to solve the formulated problems. After all, these tasks use heterogeneous information. This makes it quite difficult to create a single core for their solution, either on the basis of a neural network or with the use of knowledge bases. To create intelligent systems that are able to combine in one process disparate information, simple and cheap to build, easy to perceive and learn to respond properly to human language has long used the reflex approach. This allows you to create simple and effective systems responsive to the flow of heterogeneous data by developing reflexes to the informative component of such flows [9]. The main feature of reflex systems is the possibility of simultaneous processing of different types of input data, from separate sources as a single input stream with the production of reflexes to arbitrary combinations of elements of this data. It is most suitable for processing incoming data flow from managers, formalized and human language information from project documents, statistical information from information standard and regulatory information of project planning management.

Consider the problem of developing a response to the flow of arbitrary input data in solving intellectual problems in project planning systems.

2.2. The structure of the reflex intelligent project planning system

The main task of the reflex intelligent system of project planning (RISPP) is to create a topology of the network model PSND, to determine the parameters of work and resources. This task is performed on the basis of information about the content of the project and the physical scope of work. To solve this problem, the project planning system must: receive information on the content of the project and the physical scope of work; use the information standard of the project-oriented company to take into account previous experience in planning and implementation of project plans to set / adjust the duration of work and resources; prepare information for software that performs the function of calculating PSND (e.g., MS Project). To do this, the intelligent system must, in accordance with the information coming into the system, form an array of data for the calculation of PSND. The application of the reflex approach allows for different sets of input data to determine the corresponding elements of the data set for the calculation of PSND by generating reflexes on individual elements of this data.

Based on this, the reflex intelligent project planning system can be represented by the structure shown in Figure 1. The key modules are two: the reflex generation module and the reaction generation module. Consider methods of producing reflexes and developing reactions that are based on a reflex approach to building intelligent systems.

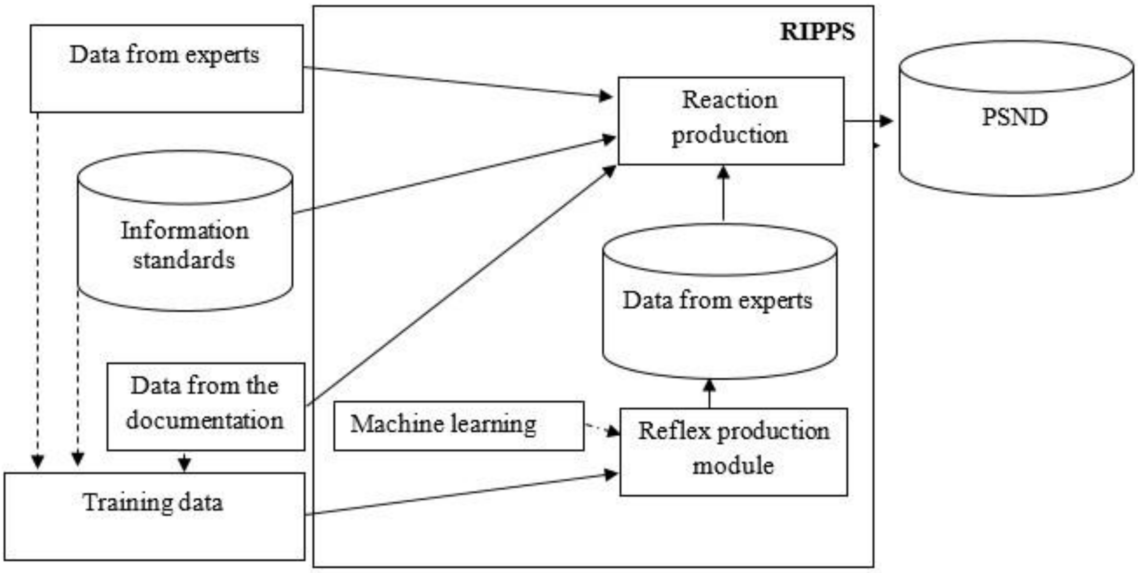

Figure 1: Macrostructure of the reflex intelligent project planning system

2.3. Development of reflexes for the flow of input data in RISPP

Under the RISPP reflex we will understand the stereotypical reaction of the intelligent system to the input data stream, which reflects the statistical regularity of the correct response of the system to individual elements of this input data stream generated by the instructor in the process of machine learning. Thus, the development of reflexes is the accumulation of statistical information on the elements of the input data and the reactions that were identified by the instructor when these elements appeared.

The illustration of the reflex can be seen in the following example. The correct reaction of the project planning system to the appearance of the element in the input data stream: The milestone "Start of the project" is the introduction of the PSND work "Start of the project" with a duration of 0 days. If several such elements appear, the system produces a reflex: If there is a word "milestone" in the input data stream, the duration of such work will be 0 days. Or when texts appear that contain the phrase "start work A after work B", a reflex is produced on the combination of the words "start… after…", which consists in the reaction "connection between works - finish-start".

At the heart of reflexes is statistical information on the causal relationship between the input data stream and possible reactions. At the heart of this statistical relationship is the conditional probability:

$$p\left(R_j/E\right), \qquad (1)$$

where Rj is the reaction of RISPP; E - input data stream.

If there are several possible reactions, the RISPP should choose the one that has the highest conditional probability

$$R_j \left| \max_j p\left(R_j/E\right). \right. \qquad (2)$$

In general, the input data flow is practically not repeated in project planning systems. Accordingly, it is impossible to accumulate statistics to select the most likely reaction (formula 2). Therefore, in the project planning system, it is proposed to divide the input data stream into elements that can be repeated in different input streams, and to produce reflexes on these elements. With the choice of the reaction to which the reflexes are strongest.

The input data stream in accordance with the presented structure (see Figure 1) includes:

1. Text in human language from members of the project management teams, which determines the reactions of the RISPP. In essence, the elements of such an input data stream can be sentences, words, letters. But it is impossible to collect the statistics necessary for learning from repeated sentences. It would be best to use words. On the one hand, the conditional probabilities of certain

reactions to words can be quite significant. But on the other hand, modern speech recognition systems. But on the other hand, modern speech recognition systems quite often make mistakes in the interpretation of words, and even managers use different terms to define the same reactions. Therefore, it was decided in RISPP to use letter combinations of different (from 2 to 10 characters) length. This increases noise immunity (you can make mistakes in words, then the reaction will be formed on the part of the sentences that are written without errors).

2. Project documentation (for construction - DBNs, design and estimate documentation, contracts, etc.). In RIX information is presented in two ways:

2.1. In human language form (the method of processing such an input data stream is discussed in claim 1).

2.2. In the form of a frame. Where the name of the slot specifies the project parameter, and the value of the slot is recorded as a data element from the documentation. In this case, the RISP produces reflexes for the frame name and the slot name. Example:

{Frame name: trench digging work;
slot name 1: volume, slot value 1: 100 m3;
slot name 2: duration, slot value 2: 3 days;
slot name 3: resource, slot value 3: JCB JS175W full-turn excavator;
…
}.

The data elements for RISPP are the frame name and slot names. Reaction - setting the value of the corresponding frame name (work) and the name of the parameter slot. In the example of the reflex on behalf of the frame "trench digging work" - to set the parameters of work. Reaction to frame names - definition of work for establishment of values of the parameters set in slots.

3. Data of the information standard. The information standard is supplemented with data on implemented projects and is statistical information on the deviation of the fact of implementation from the plan in previous projects. For use in RISPP data of works and resources are presented in tabular form (Table 1 - table 2).

Table 1
Representation of the input flow of data for works on the information standards

Project name: Logistics center construction project							
ID	Work	Planned duration				Actual duration	Connections (ID, Type, Delay)
		Expert 1	Expert 2	…	Expert N		
7001	Obtaining a construction permit	30	45		60	78	7000, FS, 0

Table 2
Representation of the input flow of data for works on the information standards

Project name						
Work ID	Resource	Planned amount				Actual amount
		Expert 1	Expert 2	…	Expert N	
7001	Representative expenses	10000	5000		12000	5000

2.4. Development of reactions in RISPP

The response of RISPP is to form a data element or perform an action to calculate the project plan. The reaction must correspond to the content of the input data stream. The reactions of the reflex intelligent system to the input data stream can be:

1. WBS project structure

2. Project resources.
3. Project work, the relationship between them and the parameters (time, cost, volume).
4. Action to calculate the project plan.

The choice of reaction is based on the assessment of the total conditional probability of possible alternative reactions to the input data stream. The reaction that has the highest probability is selected based on the reflexes produced in the RISPP.

We estimate the total conditional probability of possible alternative reactions to the input data stream as a reflex response to stimuli in living beings. If reflexes are made on separate stimuli, and many influences (many stimuli) are exerted on a living being, then the strongest reflexes "work". For RISPP, this rule can be paraphrased as follows. If reflexes are made on data elements, and the input data stream consists of many elements, the reaction which corresponds to the strongest reflexes is chosen, it “triggers” the strongest reflex. To implement this rule, it is necessary to be able to assess the "strength of the reflex". In the reflex approach, such a force is determined by the difference in the conditional probabilities (in the presence of influence, and without influence) of the probability of reactions. Namely [9]:

1. Provided $0 < p(R_j/e_i) < 1, 0 < p(R_j/\overline{e_i}) < 1$:

$$\forall R_j, e_i: \delta_{ij} = \frac{p(R_j/e_i) - p(R_j/\overline{e_i})}{2 \cdot \sqrt{p(R_j/e_i) \cdot (1 - p(R_j/e_i)) \cdot p(R_j/\overline{e_i}) \cdot (1 - p(R_j/\overline{e_i}))}}, \quad (3)$$

where δ_{ij} is the increase in the effect on the reaction R_j associated with the appearance in the input data stream of the element e_i; $p(R_j/e_i)$ – conditional probability of reaction R_j in the presence of the element e_i in the input data stream; $p(R_j/\overline{e_i})$ – conditional probability of reaction R_j in the absence of the element e_i in the input data stream.

In the general case, if there is a significant number of elements of the input data stream (and for the planning system it is), you can take

$$p(R_j/\overline{e_i}) \approx p(R_j),$$

where $p(R_j)$ is the unconditional probability of the reaction R_j.

2. The total increase in the influence of all elements of the input data stream on the reaction R_j:

$$\Delta_j = \sum_{e_i \in E} \delta_{ij}, \quad (4)$$

where Δ_j is the total increase in the effects of all elements of the input data stream on the reaction R_j; E - input data stream.

3. The overall effect on the reaction $R_j \forall R_j$:

$$d_j = \Delta_j \cdot \frac{1}{4 \cdot p(R_j/\overline{e_i}) \cdot (1 - p(R_j/\overline{e_i}))} + \sqrt{(\Delta_j)^2 + 1} \cdot \frac{p(R_j/\overline{e_i}) - 0{,}5}{2 \cdot \sqrt{p(R_j/\overline{e_i}) \cdot (1 - p(R_j/\overline{e_i}))}},$$

where d_j is the value of the total influence of all elements of the input data stream on the reaction R_j.

4. Estimation of the probability of choosing the reaction R_j, which corresponds to the magnitude of the influence of the input data stream:

$$\forall R_j: \hat{p}(R_j/E) = 0{,}5 + \frac{d_j}{2 \cdot \sqrt{d_j^2 + 1}}, \quad (5)$$

where $\hat{p}(R_j/E)$ is an estimate of the probability of choosing the reaction R_j, if the system receives the input data stream E.

The choice of reaction is performed in accordance with formula (2).

As can be seen from this representation of the modified (for the production of reflexes on the input stream of inhomogeneous data) reflex method, it is quite simple. Its effectiveness has been proven by both practical developments and experimental studies [9]. Thus, it is this method that will form the basis of project planning with a reflexive intelligent system.

2.5. Software and information environment of the reflex intelligent project planning system

In subsections 2.3 and 2.4 the input and output information of RISPP is considered. Processing of input data streams with the production of adequate information contained in these reaction data is performed according to the following generalized algorithm:

1. Determination of the content of the input data stream (what meaningful information it carries).
2. Determination of a meaningful scenario of actions (algorithm implementation of the content embedded in the input data stream).
3. Distribution of fragments of the input data stream by elements of the meaningful action scenario.

In the process of modeling project planning actions, 26 meaningful scenarios were developed, which could be implemented in 113 action scenarios (an example of meaningful action scenarios is given in Table 3).

Table 3

An example of meaningful action scenarios

Text	Content	A meaningful action scenario
Add the task of obtaining data for writing a technical task for performing topo-geodesic studies to the Topo-geodesic studies node	Add a task to a group	+task; task; +in;task
Start the Concept Expertise task after Developing a New Concept	Communication "finish-start"	+start; task; +after; task
Add resources to the node Selection of a contractor by shooting range	Add resources to the task	+resource; task

Based on the presented generalized algorithm for developing reactions to the flow of input data, and taking into account the need to develop reflexes for input flows of information with different purposes and their fragments, we offer the following structure of the information base and software tools.

The information database will contain two groups of tables: tables of intelligent modules for generating reflexes and developing reactions and tables of the project plan. Three tables are used to display reflexes: U_S, U_A, U_R. The UML diagram of the database is shown in Fig. 2. The purpose of the tables and the description of the fields are given in table 4.

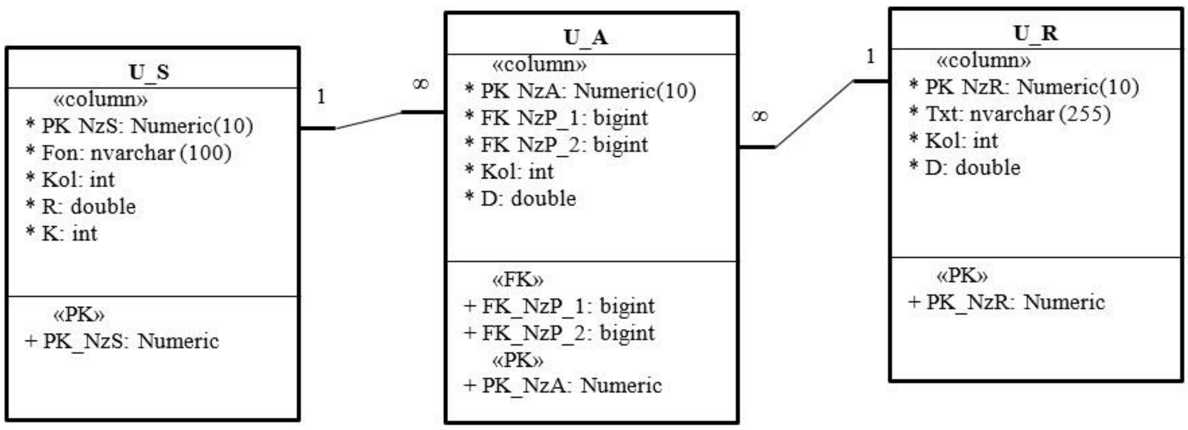

Figure 2: UML diagram of the local RISPP database

Table 4
Representation of the input flow of data for works on the information standards

Table	Field	Type	Purpose
U_S - input elements	NzS	Numeric	Record ID
	Fon	Nvarchar	An input data stream element
	Kol	Integer	How many times occurred in the input data stream
	R	Double	The amount of heterogeneity of alternatives
	K	Integer	The number of alternative reactions when an element appears
	NzR	Numeric	Record ID
U_R - reactions	Kol	Integer	How many times occurred in the input data stream
	Txt	Nvarchar	Reaction
	D	Double	Average effect on response
U_A is the connection between U_S and U_R	NzA	Numeric	Record ID
	Nzp_1	Bigint	The element ID of the input data stream
	Nzp_2	Bigint	Reaction ID
	Kol	Integer	How many times was this reaction when this element appeared
	D	Double	The magnitude of the effect of the element on the reaction (formula 3)

To increase speed and ensure the possibility of parallel processing of information with different purposes in the system, a separate physical database was created for each class of reactions. These were located independently of the others on a physical medium or in the Cloud. Moreover, the structure of each database corresponded to the diagram shown in Fig. 2. These databases were not connected to each other, as they contained different information for the production of different classes of reactions.

A total of 12 databases were created by type of reactions (which contain the tables shown in Fig. 2) for the formation of reflexes with the development of reactions to control the planning and formation of PSND:

Database 1. Determining the content of the action in the scheduling system, which is set by the input data stream (BA_00). Table U_R of this database contains meaningful action scenarios. Content options are shown in Table 4.

Database 2. Defining a meaningful action scenario (BA_01). In Table U_R of this database there are options for the content of actions. An example of meaningful action scenarios is given in table 4.

Database 3. Relationship of fragments of the input data stream with the elements of the meaningful action scenario (BA_02). Table U_R of this database shows the relationship between fragments of the input text and the content of actions. It is used to select one of the following databases for processing fragments of the input text (for example, job or resource name, job duration, etc.).

Database 4. Project works (BA_03). The reactions in this database are project works.

Database 5. Project resources (BA_04). Project resources are added (in the learning process) to Table U_R as reactions.

Database 6. Projects (BA_06). In Table U_R - company projects.

Database 7. Duration of works (BA_07). Reactions - how many days the work will last.

Database 8. Volumes of resources (BA_08). Reactions are the amount of resources.

Database 9. Units of measurement (BA_09). In Table U_R are units of measurement of resources.

Database 10. Relationships between works (BA_33). A reaction is a type of communication between robots.

Database 11. Robot resources (BA_34). Table U_R – shows the ratio of resources to works.

Database 12. Lag / advance of related works (BA_10). It is used to determine the delay/advance of the subsequent work in relation to the preceding work.

In addition, internal tables of project plans were created in the RISPP environment (outside of the given databases), which were not related to each other. They were used to display the information formed during the work of the RISPP in the environment of instrumental software tools (including MS Project):

1. Projects (_Mod06).
2. Project work (_Mod03).
3. Letter of resources (_Mod04).
4. Handbook of time measurements (_Mod07).
5. Directory of units of measurement (_Mod09).
6. Handbook describing the links between the works (_Mod10).
7. Relationships between works (_Mod33).
8. Resources for robots (_Mod34).

The use of tables of intellectual modules for developing reflexes and developing reactions of each base was determined by the definition of the content and meaningful scenario of the action, which is the essence of the input data flow. A method was proposed and an algorithm for controlling the process of content identification, content scenario and RISPP reaction was developed. The method allows it to gradually determine the content of the input data stream in relation to the actions to be performed in the project planning process. Main stages:

1. Obtaining the input data stream.
2. Determining the content of the input data stream (database BA_00).
3. Defining a meaningful scenario of the input data stream (database BA_01).
4. If the meaningful action scenario does not correspond to the content - clarification from the operator. Return to item 1.
5. Step-by-step processing of the meaningful action scenario.
6. Selection of the next element of the meaningful action scenario.
7. Defining a fragment of text related to the next element of the meaningful scenario of actions (base BA_02, base of directories: BA_03, BA_04, BA_06).
8. If the response of RISPP is a command to planning - the execution of the command in the planning management module.
9. If the reaction of RISPP is an element of the project plan - filling in the relevant table of the project plan.
10. If the meaningful scenario is not fully processed - then transition to paragraph 6.
11. End of work.

The system activity diagram is shown in Fig. 3.

A demonstration version of the reflective intelligent project planning system has been developed, which is configured for the input data stream in the form of text in human language, which can come from all sources specified in paragraph 2.3 - from members of project management teams, information standard and documentation. This system performs the following functions:

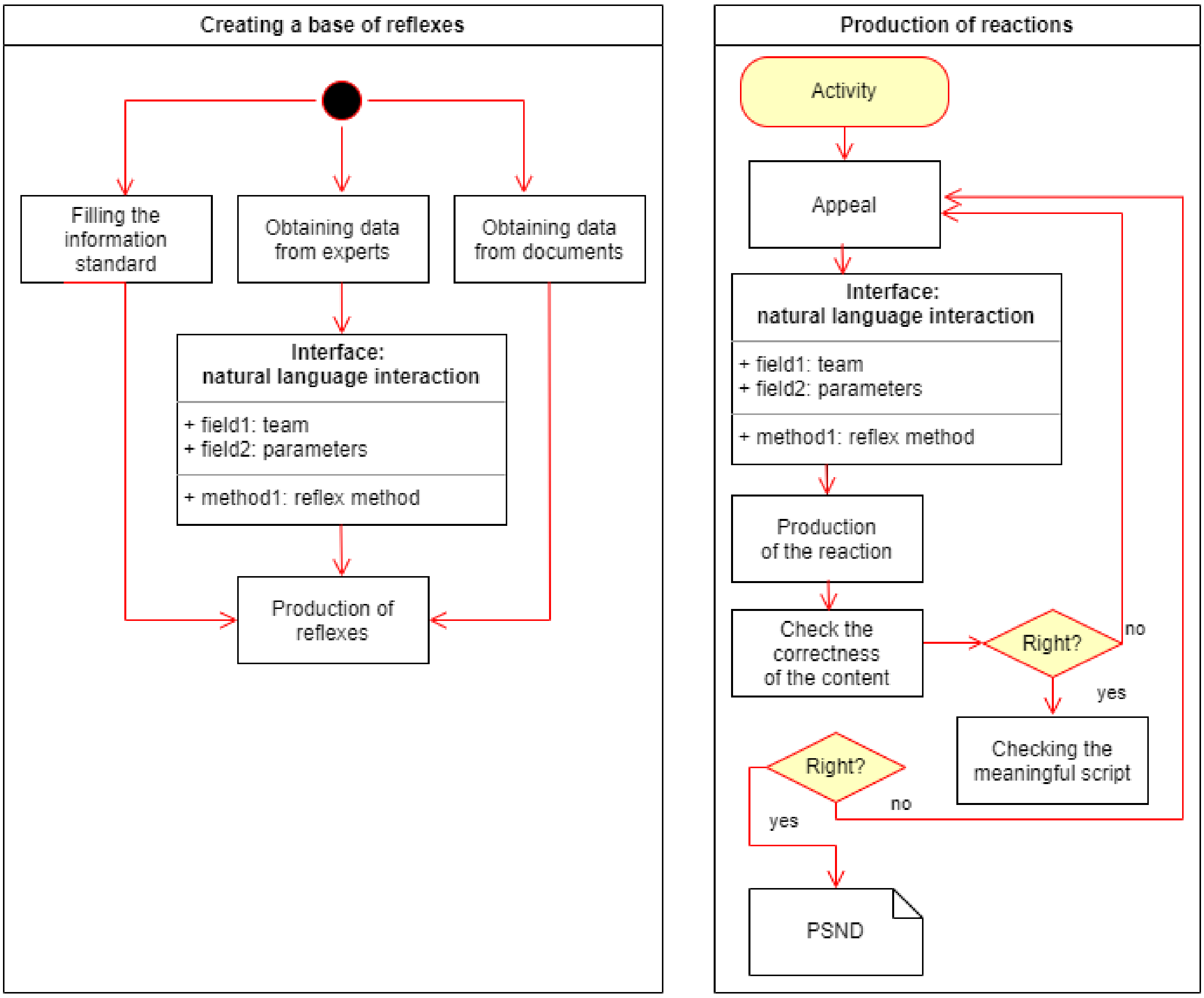

Figure 3: UML activity diagram RISPP

1. Processes arbitrary input data streams.
2. Learns (with the help of an instructor) to respond properly to incoming data streams.
3. Implements actions for preparation of PSND (forms tables of project works, communications, resources).
4. Memorizes the context. If the incoming data stream determines a project or node of work, then in the future the system is working with this project or node.
5. Generates various reports.

Experimental studies were conducted using a demonstration version of RISPP [10]. The research was conducted with PSND of 2 different development projects. The uniqueness of works in these projects amounted to more than 90%, and the uniqueness of resources - to 100%. The project plans contained 1,221 jobs and about 1,000 connections. Resources were used in 919 works. It was assumed that this information could come from project management team managers, from the information standards, and from the documentation. To make the system more reliable, the input data streams were distorted by replacing or removing 10% and 20% of the letters. The input data streams (more than 3000) contained information on project creation, tasks and resources, establishing links between works, allocating resources by works and setting numerical parameters: duration of works, amount of resources, lag / advance of works. Experimental studies have shown the high efficiency of recognizing the content of human language appeals. The probability of correct definition of the content for undistorted texts was about 97.42%, and the content scenario reached 92.68%. For the distorted it was: for 10% distortion - the content of 96.80%, the meaningful scenario - 88.89%; for 20% distortion - content 95.31%, meaningful scenario - 86.80%. The implementation of the module for cancellation of incorrect actions (cancellation/incorrect/rollback/deviations) in RISPP gave a result that allows us to proceed to the creation of an industrial reflexive intelligent project planning system.

3. Results

Methods, algorithms and demonstration tools of the reflex intelligent system of project planning are developed. It is proposed to divide the structure of the information database by the type of reactions into 12 databases. Each database is used to generate responses in terms of planning management and the formation of PSND to calculate the project plan. PSND formation is performed in sections: WBS; project works; resources and their volumes required to carry out project work; connections between works. Algorithms and software tools for teaching RISPP on educational data have been developed. In the process of learning in RISPP reflexes are developed to determine the reactions that are adequate to the content of the information coming into the incoming data streams. In the project planning process, these reflexes are used to determine the actions of the intelligent system for the formation of PSND, which is used to calculate the project plan. This made it possible to achieve the goal of the research - to develop a reflexive intelligent system of project planning, which is capable of forming the PSND of the project with minimal human participation. The system was tested in experimental studies. The results of experimental research have shown that the developed system allows to quickly and efficiently build PSND based on the use of standard information and verbal interaction with the project team. At the same time, human participation in solving this creative task is limited due to the increased intelligence of the project planning system. This, in the long run will lead to the development of more realistic plans, and thus increase the likelihood of clear work of managers and executors to implement projects "according to plan".

4. Discussion

These results made it possible to achieve the goal of the research, namely to develop a reflexive intelligent system of project planning, which is capable of forming the PSND of the project with minimal human participation.

The limitations of this study are that the system only generates a Project Schedule Network Diagram for use in the CPM method. And the functions of the calculation itself, as well as the use of other methods, in particular the PERT method, are not considered. Although based on the fact that the system is based on statistics of previous projects, the use of the PERT method to determine the optimistic, pessimistic and probable deadlines for project completion would be appropriate.

The point of discussion is the use of a reflex approach to create an intelligent planning system, rather than, say, neural network technologies. First, it involves the use of different types of data that influence project decisions (verbal and formal). Secondly, the use of neural networks involves significant costs for building and training a network capable of recognizing some reaction in the incoming data stream. Especially if the input data stream is divided into elements. So, for example, in the course of experiments 135,857 elements were allocated. And despite such a large number of elements on which reflexes are made, the reaction of RISPP to the incoming data stream was almost instantaneous (less than 1 second). In this case, when new information appears, such a neural network must be retrained. This problem is absent in reflex systems. They choose reactions in accordance with developed reflexes, which are based on statistics.

The disadvantage of the study is that the methods of building expert systems, in particular, the knowledge base, are not used. This could significantly expand the capabilities of such a system.

But as seen from the results of experimental research - the system is simple and effective and can be used in practice by project managers responsible for planning.

5. Conclusion

Research has been conducted on the development of a reflective intelligent project planning system that would be able to form a PSND project with minimal human involvement, which therefore requires the use of:

- project management methods, to determine the data that will be processed in the system and to determine the set of actions required in the process of creating a PSND and calculating the project plan;
- information technology methods - to collect information to develop a project plan;
- statistical methods and methods of artificial intelligence - to create an intelligent project planning system;
- methods of computational linguistics - for processing human language information.

As a procedural core of the system, a modified reflex method was used, with adequate actions for the formation of the project plan on the basis of information, expertise and documentation accumulated in previous projects.

The new scientific result is digital project management technologies through the use of a reflex approach and a method of forming PSND with minimal human participation. This work makes a significant contribution to the creation of digital project management. The obtained result intellectualizes the project planning process, which reduces the cost of creating a project plan and increases its accuracy and realism. Which in turn will increase the likelihood of timely implementation of the project plan.

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