The object of research of this work is the processes of project planning and monitoring. The solved problem is the development of a model, method and structures of a multilingual intelligent project planning and monitoring system and its experimental verification of the ability to understand the statements of managers in different languages.

The requirements for such a system are formulated. An analysis of the existing theoretical and practical developments in this area was carried out. It was established that there are no developments in the field of project management that can adapt to new natural languages. It was found that the formulated requirements can be satisfied within the framework of the reflexive approach. It is characterized by simplicity, continuity, and insensitivity to errors in natural language statements. To confirm these assumptions, an experimental multilingual project planning and monitoring system and experimental research methodology were developed.

The results of the experiments obtained during the use of the created experimental system testify to the correct identification of the content of appeals to the intellectual system in 6 languages with a probability higher than 0.99, and to recognize the structure of statements with a probability higher than 0.98. And the time for configuring the system to work with a new language did not exceed 1 hour. This allows to use it for practical work in distributed management systems for remote interaction of managers and specialists with the system in different languages.

The conducted experiments confirmed the assumption about the effectiveness of the reflexive approach for creating project management systems.

The developed model, method, structures, and system can be used for different types of projects, such as regional development projects, IT, etc.

Keywords: project planning, project monitoring, multilingual systems, reflexive method, information interaction

DEVELOPMENT OF A MULTILINGUAL INTELLIGENT PROJECT PLANNING AND MONITORING SYSTEM

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1. Introduction

Despite the wide development of project management, world experience shows that many projects of territorial development, construction, IT, etc. fail [1]. This indicates the need for and importance of improving project management processes. And this is impossible without the development of the knowledge industry in the field of project management,

without the use of modern information technology tools and project management methodology, without quality information about management processes. For this, a business environment based primarily on intelligent technologies and tools must be created.

This relates to the mega-trends of the development of the world economy, which are defined by the term Industry 4.0. Global computerization, automation, digitization, and the use of artificial intelligence tools lead to the fact that more and more functions are transferred to the computer, in particular decision-making functions, and less and less remains for humans. Therefore, it is no longer about the implementation of tools that solve individual project management tasks (for example, planning, procurement management, financial management, etc.), but about digital project management, which adapts project management methodology to the peculiarities of work in a digital environment. Developments in the field of artificial intelligence provide even more opportunities for digital project management. This direction allows to transfer even more project management functions to the computer, which can be implemented with minimal human involvement. The main global trends in IT development in general and in project management speak for this.

But the industrial use of such systems is still far away. Several factors prevent this. First, the multifaceted nature of actions that must be implemented in project management is quite significant. Therefore, it is very difficult to create an intelligent system that can implement the entire range of management functions without (or with minimal) human participation. Secondly, the existing methods of creating intelligent systems (neural networks, knowledge bases) require a large amount of expenses and efforts of specialists, and money for setting up intelligent systems for solving project management problems.

But the challenges that exist today in the world, and particularly in Ukraine, will increasingly require the involvement of professional project management specialists, for instance for Ukraine post-war recovering. Therefore, the task of using intelligent project management systems in the conditions of a shortage of professional specialists in various projects in the world, and particularly in the reconstruction projects of Ukraine, is extremely urgent.

It can be concluded that modern research on the creation of intelligent tools is aimed at a new era of project management development – the era of digital project management is scientifically and practically important. The developed tools can be used for any type of project, regardless of its complexity or direction. For example, they can be effectively used for projects of Ukraine post-war recovering, for the development of its infrastructure, energy, transport, education, culture, tourism, sports, etc. Therefore, the topic related to the creation of a multilingual intelligent project planning and monitoring system (Multilingual Intelligent Project Planning and Monitoring System – MIPPMS) fully corresponds to these trends and is relevant.

2. References analysis and problem statement

Project-oriented companies implement projects related to their field of activity. These are engineering, investment, construction, production, research and other projects. And in all these projects, for their successful implementation, it is necessary to effectively plan, monitor and control projects.

The main goal of planning and monitoring is to increase the efficiency of project management. And for this, in the conditions of digital transformation of project management, it is necessary to use modern software tools.

The development of information technologies, from systems that only manage project planning and resources, to complex systems that function at the project level, is presented in works [2, 3]. These works highlight the main trends in the development of tools. A favorite in this area is IBM Planning Analytics [4]. It is an integrated system that uses artificial intelligence and machine learning technologies to manage data and solve planning problems in various areas of business. Intelligent project management software products have different orientations and functionality: the ability to provide recommendations for project implementation, checking and reducing the risks of concluding contracts, forming and setting up an effective team, etc. The most famous are: PMOtto.ai, Aurora, [5]. Studies [6, 7] also present such systems as: Liquid planer, Lili.ai, Autodesk Construction IQ, Infosys Nia Contacts Analysis, TARA AI, PineStem, Forecast and others. But free tools have limited functionality, and the «boxed» version of the system does not meet the requirements of individual enterprises. The analytical component of the software is reflected in the paper [8]. The authors compare different project management information systems. But the paper does not clearly distinguish information technologies for project planning and monitoring. From the analysis of the work [9], it was concluded that the PRP-system should be used both for planning and project monitoring. Using the simulation module, the search for the best solutions is carried out taking into account the functioning of the entire enterprise. The disadvantage of the system is that it does not provide teams dependency. This question was reflected in the Celoxis system [10]. Celoxis has an intelligent scheduling tool that allows to schedule resources based on project dependencies. But there are no command manipulators in the system. The Aurora system [11] is focused on solving complex, mission-critical planning tasks with complex constraints, including expert judgment and expertise. Such a system has a transnational character, but it is not entirely convenient to adjust projects. In turn, a convenient adjustment is offered in the system [12] – a scheduler with intellectual support, which, upon receiving the input values of changes in the project (change of terms, resources, or priority of work), allows to propose an adjustment of the project plan.

The implementation of the intellectualization of the project planning process is highlighted in work [13] in the form of a software application consisting of several interacting modules with online interaction. An application in which a set of optimization methods shows the possibility of compromises. The architecture of the presented application does not involve integration into the company's project management system. This shortcoming was eliminated in [14]. But the presented product has a complex interface and a complicated system of integration into the management system. In addition, the issues of determining the relationship between the project's tasks, resource allocation and estimation of the time required for each of the works, and risk assessment remain open.

Research [15] developed a new technique based on genetic algorithms that automatically determines the programmable objective function, the optimal resource allocation, and the resulting schedule that satisfies a given task structure and resource pool. But according to this method, it is difficult to implement work scenarios in planning and monitoring projects.

The optimization method for multi-objective graphical resource constraint, which evaluates several alternative resources during each activity, is shown in the article [16]. In [17] it is proposed to model the dynamic planning of resources for several projects in time as a multi-agent system, where agents negotiate resources through an auction mechanism. Using these methods, it is difficult to analyze information about the efforts of labor resources and suppliers on previous projects for intellectual analysis, cost and duration of the project. The issue of summarizing complex input-output relationships between data sets of historical information is covered in [18]. The paper proposes the use of artificial neural networks for cost and duration planning. The disadvantage is that the model does not form a WBS structure. In the article [19], the technology of neural networks is used from the point of view of project efficiency forecasting, cost estimation, and winning bid forecasting. The disadvantage of the work is that it is difficult to adapt the algorithm to different industries. The paper [20] presents the advantages of neural network planning technologies among other methods, but the question of the technical part – the use of multilingualism – remains open. The continuation of this issue is presented in the developments of computer linguistics. The work [21] presents a system for converting text into speech based on a deep neural network. Such systems are not used in project activities. The disadvantage is that such systems involve the use of certain algorithms, which usually require a lot of computing and information resources.

The elimination of this shortcoming is proposed by the application of a reflexive approach to the construction of an intelligent project planning system, which is reflected in the work [22]. In particular, the technology of reflexive identification of actions in design systems, based on the model of non-force (informational) interaction, is proposed [23]. The shortcoming of the work is that the work does not address the issue of generating a realistic work plan based on the analysis of historical information and presenting it in management software tools. The work [24] does not cover the issue of convenient interaction of the manager with the system using voice commands in different languages, regarding the duration and interconnection of activities, the distribution of resources in project management, etc.

Thus, the analysis of the sources showed that the majority of studies are aimed at solving issues related to the automation of project management processes. Despite the received scientific and practical results, the issue of creating functionally complete multilingual intelligent project planning and monitoring systems has not been sufficiently reflected in publications. The presence of an unsolved part of the problem, namely the lack of multilingual intelligent project planning and monitoring tools, which are implemented in digital project management, necessitates the research proposed in this paper.

3. The aim and objectives of the study

The aim of the study is to develop a model and method of a multilingual intelligent project planning and monitoring system capable of forming plans for complex projects, in particular Ukraine post-war recovering. This will make it possible to create intelligent project management systems that will be able to interact with members of project teams in many languages and independently solve the tasks set by them.

To achieve the aim, the following objectives must be solved:
– to develop a model of information interaction of managers and specialists engaged in the processes of project planning and monitoring (hereinafter - project planners);
– to analyze the structure of natural language statements that reflect the interaction of teams with project planners;
– to develop a reflexive method of processing natural language information regarding project planning and monitoring;
– to develop a method of experimental research to assess the effectiveness of MIPPMS in processing language-independent natural language information for project planning and monitoring;
– to conduct experimental studies of MIPPMS and interpret their results.

4. Materials and methods of the study

The object of the study is the processes of project planning and monitoring. The subject of the study is the reflexive method of building language-independent means of project planning and monitoring. The research hypothesis is that the reflexive method will allow to create a language-independent intelligent system of project planning and monitoring.

In the work, a simplification is adopted regarding the variants of natural language appeals of project planners. 173 versions of addresses in 6 languages are used – Ukrainian (hereinafter referred to as Ukr), Russian (Rus), English (Eng), German (Deu), Slovak (Slo) and Chinese (Chi).

The assumptions of the work are that the intelligent project planning and monitoring system that works effectively in six languages will be effective in other languages as well.

The following methods were used in the research process:
– project management to build algorithms for the intelligent system of project planning and monitoring;
– linguistic analysis of the natural language interaction of project planners;
– a reflexive method for developing algorithms for an intelligent project planning and monitoring system, which, unlike others, allows for the creation of language-independent intelligent systems;
– statistical methods for conducting and interpreting the results of experimental research, since statistical methods characterize the accuracy of the interpretation of natural language addresses and allow showing the advantages of this system over similar ones.

5. Development and experimental testing of a multilingual intelligent project planning and monitoring system

5. 1. Development of a model of information interaction of managers in the process of forming and monitoring the project plan

Analysis of planning and monitoring processes shows that data collection is based on three sources: documentation, expert information, and information standard (historical data). The availability of this information allows project planners to populate the databases of such software as MS Project or Oracle Primavera P6. This is in the case when the project is small, there is only one planner (it can also be the project manager) and all the information is at hand. When the project is large-scale, when teams of managers and specialists from different divisions of the company are engaged in the formation of the

plan, and they interact informationally (most often informationally) with project planners, then the problem of building effective interactions between them arises. It is even more complicated when the members of the project team are in different places and can interact only online.

When moving to digital project management, the planner's functions are largely transferred to the computer. More precisely, intelligent planning systems. In this case, such systems must be able to communicate with project team members. And preferably in a language they understand.

Therefore, to develop an intelligent project planning and monitoring system and conduct its experimental verification, it is first necessary to build a model of information interaction between the project team and the planner in order to translate the performance of the relevant functions into the system. The basis of such a model should be intellectual information processes of filling the content of the natural language text with information that determines the actions of the project planner. The implementation scheme of these processes has the following form (Fig. 1).
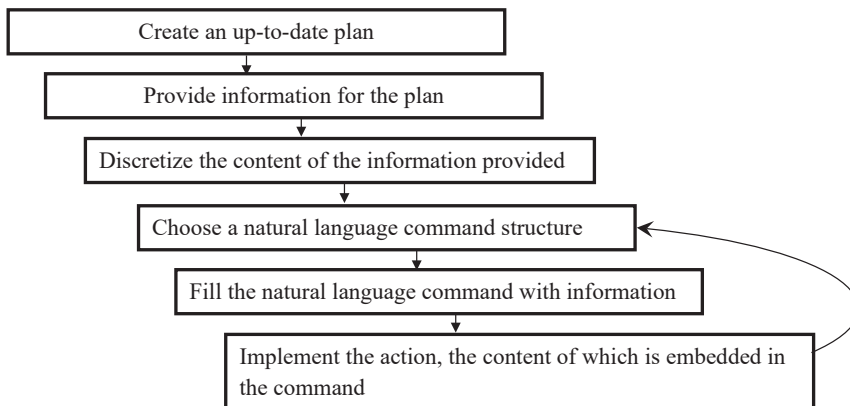

Fig. 1. Scheme of information processes of filling the content of the natural language text with information that determines the actions of the project planner

Let's present the interaction of the project team with the planner as an exchange of statements that contain all the information necessary to implement specific actions for project planning. Each statement can contain 3 main components:

1. Determination of project planning actions (set or update tasks, nodes, milestones, resources, links, etc.).

2. Definition of attributes of the subject area, in relation to which actions are performed (tasks, resources, parameters of tasks and resources, etc.).

3. Noise.

In general, the statement can be represented by a combination of the following components:

$$a_1 c_1 b_1 ... a_i ... c_j ... b_k ... a_n ... c_m ... b_l,$$

where a_i – the text that defines the project planning or monitoring action; b_k – the text that defines the domain attributes on which actions are performed; c_j – noise.

Although in real conditions, the statement most often contains one element that defines the action, 1–2 elements that define the attributes of the subject area, and several elements of noise. For example (Fig. 2).
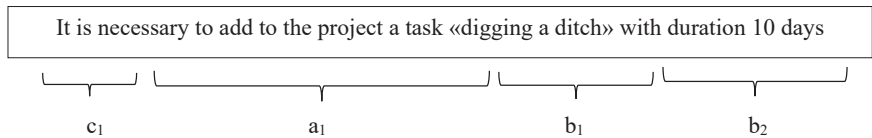

Fig. 2. An example of the structure of a statement on project planning or monitoring

In the process of interaction between the project team and the planner, a sets of elements belonging to the following classes are used:

$$E^a = \{e_i\}, i = \overline{1, n_a};$$
$$E^a = \{e_j\}, j = \overline{n_a + 1, n_b};$$
$$E^c = \{e_l\}, l = \overline{n_b + 1, n_c},$$

where E^a – a set of text elements that determine actions for project planning or monitoring; E^b – a set of text elements that define domain attributes on which actions are performed; E^c – a set of text elements that do not affect the definition of project planning or monitoring actions.

Thus, to create a multilingual intelligent project planning and monitoring system, it is necessary to develop a method for identifying the elements of the given sets, regardless of the peculiarities of the construction of managers' statements in different languages.

For this, let's use the following method. Let's perform the decomposition of the information interaction of the project team with the planner in the section of the given sets. In this case, any statement of the members of the project team can be considered as two separate statements that define the elements important for the planning system:

1. For the identification of project planning or monitoring actions, the elements that define the attributes of the subject area, in relation to which the actions are performed, will be related to noise: $e_j \rightarrow E^c$.

2. To identify the attribute of the subject area, in relation to which actions are performed, actions for planning or monitoring projects are also related to noise: $e_j \rightarrow E^c$.

When using this technique, the process of recognizing actions and the action attribute is simplified. After all, in any statement, two classes of elements are initially distinguished – actions and noise. And then – attributes of action and noise.

The following model is proposed for selecting an action and an action attribute. The determination to which class the text element belongs is carried out on the basis of decisive rules:

1. If,

$$\exists r_q \in R, e_i \cap V_s =$$
$$= \varnothing : p(r_q / V_s) < \alpha_a \wedge p(r_q / V_s \cup e_i) \gg \alpha_a, \qquad (1)$$

where r_q – action on project planning or monitoring; R – a set of actions for project planning or monitoring; e_i – text element; V_s – statement; $p(r_q / V_s)$ – the conditional probability that an action r_q must be performed when the statement V_s occurs; $p(r_q / V_s \cup e_i)$ – the conditional probability that an

action r_q must be performed when the element e_i is included in V_s; α_a – confidence probability – the marginal probability at which an action is performed, determined by the conditional probability $p(r_q/V_s)$ or $p(r_q/V_s \cup e_i)$, then:

$$e_i \in E^a.$$

2. If,

$$\exists w_u \in W, e_i \cap V_s =$$
$$= \varnothing : p\left(w_u/V_s\right) < \alpha_b \wedge p\left(w_u/V_s \cup e_i\right) \gg \alpha_b, \qquad (2)$$

where w_u – an attribute of project planning or monitoring; W – set of project planning or monitoring attributes; e_i – text element; α_b – confidence probability is the marginal probability at which the selected attribute determined by the conditional probability $p(w_u/V_s)$ or $p(w_u/V_s \cup e_i)$ is fulfilled, then:

$$e_i \in E^b.$$

3. If rules 1 and 2 are not fulfilled, then $e_i \in E^c$.

The basis of the proposed information model is the intellectual information processes of filling the content of the natural language text with information that determines the actions of the project planner. Based on the proposed model, it is possible to determine the structure of natural language statements that reflect the interaction of the team with the project planner and that should be processed by the intelligent system.

5. 2. Analysis of the structure of natural language statements that reflect the interaction of teams with the project planner

To create MIPPMS, first, it is necessary to understand in what form the team will interact with the system. To do this, at the first place, let's highlight the actions that must be performed for project planning and monitoring, and which are determined in the process of information interaction between the project team and the planner (Table 1).

Table 1

Structure of interaction during project planning and monitoring

#	The topic of team interaction with the project planner	Actions of the project planner
1	Project initiation	Define project
2	Project scope	Add new tasks (WBS nodes, activities, milestones)
3	Project scope	Set task parameters
4	Resource allocation by tasks	Assign resources to task
5	Task execution order	Link tasks (FS, SS, FF, SF, lag/lead)
6	Task execution order	All tasks in node is linked sequentially
7	What resources are needed for the project	Add resources to project dictionary
8	How task is performed	Enter task performance
9	How task is performed	Enter task completion

Of course, these are not all actions of the project planner. Many actions are performed independently, without interaction (or almost without interaction) with the project team. For example, set calendars, create a baseline, receive reports and provide them to the project team, set additional project details, etc. Since these and other actions not specified in the Table 1 do not require interaction with the project team, so they will not be considered in this work. Since it is important for digital project management that MIPPMS understands the project team and performs the actions of the planner, the structure of the statements will be adjusted precisely to the topics and actions presented in the Table 2. Although in the future its sphere of activity can be expanded to include other activities of the project planner.

In practice, the project planner performs many actions using lists. For example, count resources in a task. Therefore, a structure of statements that allow working with lists of tasks or resources is proposed (Table 3).

Table 2

The structure of natural language statements for project planning and monitoring

#	MIPPMS functions	The structure of natural language statements	Example
1	2	3	4
1	Define project	+continue; project	Create project 'R'
		+continue; project; +continue	
		project;+continue	
2	Add new task (WBS nodes, activities, milestones)	+continue; task	For 'N' add task 'R'
		+continue; task; +continue; task-2	
		+continue; task; +continue; task-2; time	
		+continue; task; time	
		+continue; task; time; +continue; task-2	
		+continue; task-2; +continue; task	
		+continue; task-2; +continue; task; time	
3	Set task parameters	+continue; task; time	Duration 'R' is 'D' days
		task; time	
4	Assign resource to task	+continue; task; +continue; resource	Assign resource 'R' with volume 'D' to task 'N'
		+continue; task; +continue; resource; volume	
		+continue; resource; +continue; task	
		+continue; resource; +continue; task; volume	
		+continue; resource; volume; +continue; task	

1	2	3	4
5	Link tasks (FS, SS, FF, SF, lag/lead)	+continue; task; +continue; task-2	Link task 'N' after task 'R' with lag 'D' days
		+continue; task; +continue; task-2; +continue	
		+continue; task; +continue; task-2; +continue; time	
		+continue; task; +continue; task-2; time	
		+continue; task-2; +continue; task	
		+continue; task-2; +continue; task; time	
6	Link tasks in node sequentially	+continue; task	Link task sequentially in group 'R'
7	Add resource to system dictionary	+continue; resource	Add to dictionary resource 'R' with volume 'D'
		+continue; resource; +continue; volume	
		+continue; resource; volume	
8	Enter task performance	+continue; task	Task 'R' 'D' % complete
		+continue; task; +continue	
		+continue; task; volume	
9	Enter task completion	+continue; task	Task 'R' finished complitely
		+continue; task; +continue	

Notes:
1. The designation +continue is an arbitrary combination of words that defines the topic of the team's interaction with the project planner.
2. Designations 'R', 'N' – in the model of information interaction are replaced by jobs and resources; designation 'D' – volume, or time.
3. Structures of natural language utterances are highlighted, for which an example is given (column 4 in Table 2)

Table 3

The structure of natural language statements for working with lists in the process of project planning or monitoring

#	MIPPMS functions	The structure of natural language statements	Example
1	Add new tasks (WBS nodes, activities, milestones)	+continue	Into group 'R' add new tasks
		+continue; task	
		+continue; task; +continue	
		task; time	
		task	
		+STOP	
2	Assign resources to task	+continue; task	Assign resources to task 'R'
		+continue; task; +continue	
		The list includes:	
		resource; volume	
		resource	
		+STOP	
3	Add resources to system dictionary	+continue	Add new resources to the dictionary
		resource; volume	
		resource	
		+STOP	
4	Enter tasks performance	+list of performance	Commit tasks execution
		task; volume	
		+STOP	
5	Enter tasks completion	+end list	The following works are fully completed
		task	
		+STOP	

Note: +STOP defines the end of the list. Can be set with statements: List has ended, Stop, End, End of list, Finished

In addition to the above expressions, service ones are used: fix the task, remove the fixation, ignore the previous request (if it was identified incorrectly).

5. 3. Development of a reflexive method of natural language information processing for project planning and monitoring

The MIPPMS reaction is influenced by the content of statements made by project team members. They are the factors of influence on the reaction of the system. Since we are considering a multilingual planning system, the use of linguistic analysis tools to calculate an adequate response would lead to a significant duration of such a project. After all, building thesauruses for each language requires significant efforts, which would practically make it impractical for real use. Therefore, it is proposed to use a reflexive approach to create a multilingual intellectual system [24]. Within the framework of this approach, reactions are made to a combination of symbols of the input text, regardless of the language in which the statement is formed, and they can be represented as follows:

1. It is accepted that for each statement there is an adequate reaction to its content. The MIPPMS reaction is understood as the execution of an action with the attributes included in the statement:

$$\forall e_i \in V_s \exists r_q \in R, w_u \in W: p(r_q/V_s) \approx 1, \tag{3}$$

where r_q – adequate for statement V_s action on project planning or monitoring; w_u – adequate for statement V_s attribute of project planning or monitoring.

Thus, the response of MIPPMS is the selection of the action and the attributes of the action.

2. The decisive rule for choosing an action:

$$r_q \mid \max_q p(r_q/V_s). \tag{4}$$

3. The decisive rule for choosing action attributes:

$$w_u \mid \max_u p(w_u/V_s). \tag{5}$$

Formulas (2) and (3) can be used in the case when the statements are repeated, and there is a statistic to obtain the conditional probability. In practice, statements cannot

be repeated, because they define one-time actions that, after execution, no longer make sense to be performed again. Repeated are the structural elements of utterances – letters, letter combinations, words, combinations of words. Such structural elements also influence the choice of action or action attribute, although not as clearly as in formulas (4), (5). But in this case, the choice can be made based on the informational influence of the structural elements of the statements on each action (attribute of the action), choosing each time the action (attribute of the action) on which the influence is maximum:

$$\forall e_i \in V_s, r_j \in R, w_k \in W \exists r_q \in R, w_u \in W:$$

$$\sum_{ei} d(r_q/e_i) \geq \sum_{ei} d(r_j/e_i);$$

$$\sum_{ei} d(w_u/e_i) \geq \sum_{ei} d(w_k/e_i), \qquad (6)$$

where r_j – action on project planning or monitoring; w_k – attribute of project planning or monitoring; $d(r_j/e_i)$ – the amount of informational influence of the text element e_i on the action r_j; $d(w_k/e_i)$ – the amount of informational influence of the text element e_i on the attribute w_k.

To create MIPPMS, it is necessary to develop a method for determining the informational influence of natural language text elements on the reaction. And put the content of the text in accordance with the correct reaction.

In MIPPMS, such a final response will be some action(s) to supplement or change the project plan and its attributes. Activity attributes include task name, duration, milestones, WBS nodes, resources and their volume, types of links between tasks, and lags/leads. For this, in the reflex method, it is necessary to implement the following steps:

1. If the probability of the reaction (action or action attribute) c_j is equal to $p(c_j)$, and when the text element e_i appears in the statement, this probability becomes $p(c_j/e_i)$, then the amount of informational influence of the text element e_i on the reaction c_j is calculated according to the formula:

$$d(c_j/e_i) = \pm 0.5 \times$$
$$\times \sqrt{\frac{p(c_j/e_i)\cdot(1-p(c_j))}{p(c_j)\cdot(1-p(c_j/e_i))} + \frac{p(c_j/e_i)\cdot(1-p(c_j))}{p(c_j)\cdot(1-p(c_j/e_i))} - 2}, \qquad (7)$$

under the condition:
– the influence is positive ($d(c_j/e_i)>0$) if $p(c_j/e_i)>p(c_j)$;
– the influence is negative ($d(c_j/e_i)<0$), if $p(c_j/e_i)<p(c_j)$;
– there is no influence ($d(c_j/e_i)=0$), if $p(c_j/e_i)=p(c_j)$;
– where $d(c_j/e_i)$ – the amount of informational influence of the text element e_i on the reaction c_j.

2. The total information influence of all text elements on the reaction c_j is calculated according to the formula:

$$\Delta d(c_j/V_s) = \sum_{e_{i \in V_s}} d(c_j/e_i), \qquad (8)$$

where $\Delta d(c_j/V_s)$ – information influence of the statement V_s on the reaction c_j.

In fact, quantity (8) determines how much the conditional probability of the reaction c_j is higher than the unconditional one. Now it is possible to an estimate of the conditional probability of the reaction c_j, which is determined by the statement V_s.

3. The estimate of the conditional probability of the reaction c_j, which is determined by the statement V_s:

$$\Delta p(c_j/V_s) = 0.5 + \frac{\Delta d(c_j/V_s)}{2\cdot\sqrt{(\Delta d(c_j/V_s))^2 + 1}},$$

$$p(c_j/V_s) =$$
$$= \frac{p(c_j) + \Delta p(c_j/V_s) - 0.5}{2\cdot\sqrt{p(c_j)\cdot(1-p(c_j))\cdot(1-\Delta p(c_j/V_s)\cdot\Delta p(c_j/V_s))}}, \qquad (9)$$

where $\Delta p(c_j/V_s)$ – conditional probability, which corresponds to the amount of informational influence of the statement V_s on the reaction c_j; $p(c_j/V_s)$ – estimation of the conditional probability of the reaction c_j, which is determined by the statement V_s.

4. From formulas (4) and (5), let's get the decisive rule for choosing a reaction:

$$c_j \mid \max_j p(c_j/V_s). \qquad (10)$$

The main advantages of MIPPMS are:
– there are no training and control samples, the training process itself is missing. In teaching of text «understanding» all previous information is used, reflected in unconditional and conditional probabilities. This significantly speeds up and simplifies the operation of the MIPPMS system, compared to systems using artificial neural networks;
– there are no heuristics, such as how much to change the connection weights and threshold values of artificial neurons;
– as can be seen from the above formulas, the algorithm for determining the most likely reaction is very simple and can be easily implemented in any development environment.

The above advantages allow to use this method to create a project planning and monitoring system. But the question remains – will such a simple method allow the project team to effectively interact with the system in different languages to solve the problems of project planning and monitoring. Experiments are necessary to answer this question.

5.4. Development of the methodology of experimental studies to evaluate the effectiveness of a multilingual intelligent system

As a result of experimental studies, it is necessary to get an answer to the question: how effective is MIPPMS for solving the problems of project planning and monitoring when interacting with the project team in different languages. For this purpose, it was determined:

1. Languages of communication. 6 languages were chosen: Ukrainian, russian, English, Chinese, Slovak and German.

2. Projects. 3 development projects were selected for planning and monitoring.

3. Attributes of actions. Attributes are tasks, resources, links between tasks, resource volumes, and task completion percentage. Number of attributes:
– projects – 3;
– tasks – 4750;
– names of resources – 306;
– resources in tasks – 4490;
– connections between tasks – 8002;
– partially completed tasks – 1,540;
– fully completed tasks – 668.

3. The number of statements required to perform actions with projects is 21,265.

4. Languages of communication. 6 languages were chosen: Ukrainian, Russian, English, Chinese, Slovak and German.

5. The names of all attributes were translated from Russian (the projects were implemented until 2014) by Google's automatic translator [25]. Of course, the quality of the translation is not perfect, but if the experiments give good results, it will testify to the wider capabilities of MIPPMS (working with poor-quality texts).

6. Formulation of statements. If the statement contains the name of the task, and this statement is not related to the entry of this task into the database, the following rules were used:

– if the length of the task title is more than 100 letters (at least in one of the languages), its number in all languages is used instead of the title;

– with the length of the task title from 50 to 99, the number was used with a probability of 0.5.

7. The number of speech templates is 188. From this number, a speech template is randomly selected for each action. In which the attribute of the project plan is automatically inserted (Table 2 – «Example» column).

8. The size of the training sample – 90 % of statements (but no more than 1000) for each type of structure (Tables 2, 3).

9. The size of the control sample is 10 % of statements for each type of structure (Tables 2, 3).

5. 5. Experimental studies of multilingual intelligent project planning and monitoring system

The conducted experimental studies made it possible to assess the adequacy of identification of project planning and monitoring actions from language-independent natural language addresses of project planners.

For this purpose, from the project plans, statements were automatically and randomly formulated for the introduction of new tasks, resources, establishing the duration of tasks, resources for task, links between tasks, tasks performance.

Statements were formulated by randomly selecting a template and filling it with attributes:

– names or numbers of tasks;

– names of resources;

– task parameters (duration, resources and their volumes, % of completion);

– resource parameters (volumes);

– links between tasks (type, lag/lead).

An example of such formulation is given in Table 4.

For each of those listed in the Table 4 statements MIPPMS defines:

1. The function that must be performed in the project management system (for example, MS Project).

2. The meaningful composition of the statement – what attributes should be highlighted and in what order they are placed.

The list of functions of the project management system for which templates were created is given in the Table 2. Examples of templates for adding a new task into the project are shown in the Table 5.

Table 4

Examples of statements in different languages regarding project planning and monitoring

Language	Expression
MIPPMS function – add task	
Ukr	Додай роботу Розробка СТАДІЇ `ПП` у вузол Фаза 4. Розробка проєкту
Chi	將工作 開發階段 "PP" 添加到節點 階段 4. 項目開發
Eng	Add work Development STAGE `PP` to node Phase 4. Project development
Rus	Добавь работу Разработка СТАДИИ `ПП` в узел Фаза 4. Разработка проєкта
Deu	Arbeit Entwicklungsstufe «PP» zu Knoten Phase 4. Projektentwicklung hinzufügen
Slo	Pridajte prácu Vývojová etapa `PP` do uzla Fáza 4. Vývoj projektu
MIPPMS function – set link «finish-to-start»	
Ukr	Виконай задачу Монтаж регілій 4 секції після завдання номер 2478
Chi	在任務 數字 2478 之後執行任務 4節導軌的安裝
Eng	Do task Installation of regalia 4 sections after task number 2478
Rus	Выполни задачу Монтаж регилий 4 секции после задачи номер 2478
Deu	Erledige Aufgabe Installation von Insignien 4 Abschnitte nach Aufgabe nummer 2478
Slo	Urobte úlohu Inštalácia regálií 4 sekcií po úlohe číslo 2478
MIPPMS function – to record works performance	
Ukr	>Внеси_виконання_роботи_Служба_автошляхів_Київської_обл._5_%<
Chi	>輸入完成的工作_基輔地區的高速公路服務。_5_%<
Eng	>Enter_work_done_Service_of_highways_of_the_Kyiv_region._5_%<
Rus	>Внеси_выполнение_работы_Служба_автомобильных_дорог_Киевской_обл._5_%<
Deu	>Erledigte_Arbeit_eingeben_Service_der_Autobahnen_der_Region_Kiew._5_%<
Slo	>Zadajte_vykonanú_prácu_Servis_diaľnic_v_regióne_Kyjev._5_%<

Table 5

Templates for adding new tasks into the project

Statement template	Statement structure
Include in node 'N' work 'R'	+continue; task-2; +continue; task
Add task 'R' to work group 'N'	+continue; task; +continue; task-2
Add job 'R' of duration 'D' to node 'N'	+continue; task; time; +continue; task-2
In group 'N' include task 'R' which will last 'D'	+continue; task-2; +continue; task; time
In node 'N' add task 'R' with duration 'D'	+continue; task-2; +continue; task; time
Add task 'R' to node 'N' with duration 'D'	+continue; task; +continue; task-2; time
New task 'R' continues 'D'	+continue; task; time
Add task 'R' to work group 'N'	+continue; task; +continue; task-2
Add work 'R' to node 'N'	+continue; task; +continue; task-2
In group 'N' include task 'R'	+continue; task-2; +continue; task
In node 'N' add task 'R'	+continue; task-2; +continue; task
Add task 'R' to node 'N'	+continue; task; +continue; task-2
Write a new task 'R'	+continue; task
Write a new task 'R' 'D'	+continue; task; time
Write a task 'R' with duration 'D'	+continue; task; time
Another 'R' job that will last 'D'	+continue; task; time
Add more work 'R' with duration 'D'	+continue; task; time
Add work 'R' with duration 'D'	+continue; task; time
Write another task 'R'	+continue; task
Include work 'R' in the project	+continue; task; +continue
Another task in the 'R' project	+continue; task; +continue
New work 'R'	+continue; task
Add node 'R'	+continue; task
Add job group 'R'	+continue; task
Add job 'R' to the project	+continue; task; +continue

According to the proposed methodology, experiments were conducted, which consisted of:

1. In the generation of a set of statements that will allow displaying the projects in the management system in full.

2. In the selection in the set of statements of the training and testing samples. Moreover, for an objective comparison of results in different languages, the same statements in different languages refer to the same samples.

3. Calculation of training samples in accordance with the reflexive method of natural language information processing in relation to project planning and monitoring of the amount of informational influence of combinations of letters and numbers of expressions (length from 2 to 8 characters) on reactions, which serve as the functions of the project management system and the structure of expressions.

4. Calculation for each statement from the control sample of its influence on the possible functions of the project management system and variants of statement structures. At the same time, only positive effects are considered.

5. Selection of the most likely function of the project management system and the most likely structure of the statement.

6. Evaluation of the correctness of the choice.

In the Table 6, the results of experiments related to the correct definition of the functions of the multilingual intelligent project planning and monitoring system are shown.

The Table 7 shows the results of experiments related to the correct definition of the structure of natural language statements in relation to project planning or monitoring.

The final result of determining the functions and structure of natural statement is given in the Table 8.

Table 6

Percentage of correctly identified MIPPMS functions

MIPPMS functions	LANGUAGE						Study sample	Control sample
	Ukr	Rus	Eng	Chi	Slo	Deu		
Define project	–	–	–	–	–	–	3	0
Add new task (WBS nodes, activities, milestones)	100	100	100	99.72	100	100	700	358
Add new tasks (WBS nodes, activities, milestones) as a list	100	100	100	100	100	100	114	10
Tasks as a list	99.15	99.15	99.15	100	99.15	100	700	117
Set tasks parameters	100	100	100	100	100	100	700	85
Assign resource to task	100	100	100	100	100	100	700	450
Link tasks (FS, SS, FF, SF, lag/lead)	100	100	99.74	100	99.12	99.74	769	760
Add the resource to the system dictionary	100	50	100	100	100	100	31	2
Add the resources to the system dictionary (as a list)	100	100	100	100	100	100	44	5
Enter task performance	100	100	100	100	100	100	242	27
Enter tasks performance as a list	100	100	100	100	100	100	700	128
Enter task completion	100	100	86.96	82.61	100	91.3	226	23
Enter tasks completion as a list	100	100	100	100	100	100	439	49
Specify the performance list	100	100	100	100	100	100	82	9
Specify the list of finished tasks	100	100	100	100	100	100	210	23
Finish list	100	100	100	100	100	100	415	46

Table 7

The percentage of correctly identified MIPPMS natural language statement structure related to project planning or monitoring

Statement structure	LANGUAGE						% correct	Sample	
	Ukr	Rus	Eng	Chi	Slo	Deu		study	control
+continue	100	100	100	100	100	100	100	54	6
+continue; task	97.25	97.25	92.96	95.24	93.81	96.49	95.64	5037	527
+continue; task; +continue	100	100	100	100	95.83	100	99.47	1614	190
+continue; task; +continue; задача−2	99.47	99.47	99.37	99.67	99.01	100	99.49	6440	2364
+continue; task; +continue; task−2; +continue	–	–	100	96.61	100	98	98.18	578	220
+continue; task; +continue; task−2; +continue; time	100	100	0	100	100	0	66.67	54	6
+continue; task; +continue; task−2; time	0	0	0	90	0	25	26.32	342	38
+continue; task; +continue; task−2; time; +continue	–	–	–	–	–	0	0	35	2
+continue; task; +continue; volume	–	–	–	100	–	–	100	42	4
+continue; task; +continue; resource	100	100	100	97.3	100	–	99.77	3691	870
+continue; task; +continue; resource; +continue	–	–	–	–	–	100	100	678	156
+continue; task; +continue; resource; volume	100	95.83	100	100	100	–	99.05	963	105
+continue; task; +continue; resource; volume; +continue	–	–	–	–	–	100	100	212	24
+continue; task; +continue; time	–	–	–	100	–	–	100	90	7
+continue; task; volume	100	100	100	100	100	100	100	1321	151
+continue; task; volume; +continue	–	–	–	–	–	100	100	89	7
+continue; task; volume; +continue; task	–	–	–	100	–	–	100	97	15
+continue; task; time	100	100	100	97.87	100	100	99.82	8517	1631
+continue; task; time; +continue	–	–	–	100	–	100	100	878	198
+continue; task; time; +continue; task−2	100	0	100	–	0	–	50	76	8
+continue; task; time; +continue; task−2; +continue	–	–	–	–	–	100	100	19	2
+continue; task−2; +continue; task	99.73	99.2	99.7	97.44	99.22	71.33	96.86	4606	1654
+continue; task−2; +continue; task; +continue	–	–	97.78	91.11	–	98.67	97.46	867	315
+continue; task−2; +continue; task; +continue; time	–	–	–	0	–	–	0	6	1
+continue; task−2; +continue; task; time	71.43	71.43	71.43	–	100	66.67	77.42	336	31
+continue; task−2; +continue; task; time; +continue	–	–	–	–	–	50	50	39	4
+continue; task−2; time; +continue; task	–	–	–	0	–	–	0	22	2
+continue; resource	100	100	–	–	–	–	100	81	2
+continue; resource; +continue	–	–	100	100	100	100	100	54	4
+continue; resource; +continue; task	100	90.18	100	100	100	100	98.62	6488	1161
+continue; resource; +continue; task; +continue	–	–	–	–	–	100	100	800	161
+continue; resource; +continue; task; volume	100	100	100	–	100	–	100	380	40
+continue; resource; +continue; task; volume; +continue	–	–	–	–	–	100	100	95	10
+continue; resource; volume	0	0	100	–	0	0	20	35	5
+continue; resource; volume; +continue; task	100	100	100	–	100	–	100	412	44
+continue; resource; volume; +continue; task; +continue	–	–	–	–	–	100	100	103	11
+performance list	100	100	100	100	100	100	100	492	54
+finishing list	100	100	100	100	100	100	100	1260	138
+STOP	100	100	100	100	100	100	100	2490	276
task	98.97	98.97	98.97	98.97	97.94	100	98.97	5202	582
task; +continue	–	–	100	100	100	100	100	255	21
task; +continue; resource; +continue	–	–	–	100	–	–	100	343	82
task; volume	100	100	100	100	100	100	100	6000	768
task; time	89.61	100	100	100	89.61	100	96.48	4070	454
task; time; +continue	–	–	–	–	–	100	100	70	8
volume; +continue; task; +continue; resource	–	–	–	100	–	–	100	95	10
volume; +continue; resource	–	–	–	0	–	–	0	2	1
volume; +continue; resource; +continue; task	–	–	–	100	–	–	100	103	11
volume; resource	–	–	–	0	–	–	0	6	1
resource	100	100	100	100	100	100	100	156	18
resource; volume	0	0	0	–	0	0	0	48	5
time; +continue; task	–	–	–	100	–	–	100	515	133
time; +continue; task; +continue	–	–	–	100	–	–	100	164	47
time; +continue; task; +continue; task−2	–	–	–	100	–	–	100	19	2
TOTAL	98.8	98.18	99.04	98.8	98.4	97.08	98.39	66441	12587

Table 8

The generalized result of the work of MIPPMS on the processing of natural language statements for project planning and monitoring

LANGUAGE	Percentage of correctly identified MIPPMS functions	Percentage of correctly identified natural language statement structure
Ukr	99.95	98.8
Chi	99.76	98.8
Eng	99.71	99.04
Rus	99.9	98.18
Deu	99.8	97.08
Slo	99.62	98.4
MEAN	99.79	98.39

Listed in the Tables 6, 7, the results of experimental studies regarding the correct definition of MIPPMS functions and the structure of natural language statements fully correspond to the tasks formulated in the paper. Namely, checking the effectiveness of the multilingual intelligent project planning and monitoring system based on a reflexive approach to building artificial intelligence systems.

6. Discussion of the results of MIPPMS development and the results of its experimental approval

The work is devoted to the creation and experimental verification of a multilingual intelligent project planning and monitoring system.

The basis of the system is a model of information interaction between managers and specialists engaged in the processes of project planning and monitoring. This approach made it possible to eliminate the intermediate link – the project planner – from the planning and monitoring processes, which minimized human participation and the impact of its mistakes on these processes.

The model contains a diagram of the information processes of filling the content of the natural language text with information that determines the actions of the project planner (Fig. 1), the structure of statements on project planning or monitoring (Fig. 2) and decisive rules (1) and (2). This made it possible to analyze the structure of natural language statements that reflect the interaction of teams with project planners. The results of the analysis are presented in Tables 1–3.

In contrast to the traditional methods of natural language processing with the construction of linguistic processors and neural network technologies, which was studied in chapter 2 [18–21], the reflexive approach was used in the work. It is based on an element-by-element representation of the structure of natural language utterances and the calculation of their influence and the choice of actions or attributes of actions. This method is represented by formulas (3)–(10). Its use made it possible to simplify the process of developing and configuring the system for a new language of communication and make it resistant to inaccuracies and errors in natural language statements.

The resulting decisions regarding the application of the reflexive approach made it possible to create a language-independent method and a multilingual intelligent project planning and monitoring system and to confirm their high efficiency.

The results of the research on the development of the model, the formalized structure of natural language statements and the language-independent reflexive method of processing natural language information regarding project planning and monitoring formed the basis of a multilingual intelligent system of project planning and monitoring. To prove its effectiveness, a method of experimental research was developed to evaluate the effectiveness of MIPPMS in processing language-independent natural language information for project planning and monitoring. The peculiarities of the methodology are settings for language-independent processes of information interaction while ensuring the same standards for assessing the results of planning and monitoring projects in different languages.

Based on the proposed methodology, MIPPMS experimental studies were conducted. The results of these studies confirmed a high probability (0.98–0.99) of the correct implementation of project planning and monitoring actions even without the participation of the intermediate link of these processes – the project planner.

The results obtained, namely the creation of an intelligent project planning and monitoring system and its experimental verification, allow to talk about a new direction in the development of digital project management – the creation of multilingual intelligent project management tools.

The developed system allowed practically, with minimal human involvement (project planner), to perform functions that are not presented in the works [14, 15, 18]:

– form a digital foundation of project management processes, which will include projects, WBS, tasks, milestones, resources and their content (volumes, execution time);

– form a network schedule in the process of direct interaction of the project team with the intelligent system;

– monitor the project and enter information on project implementation;

– perform all these functions in any communication language.

The use of the developed system allows to increase the accuracy and speed of decision-making, which is especially important in cases of restoration of territories. And also to integrate representatives of different countries, who interact in different languages, are responsible for different spheres of activity, have their own vision for the implementation of project plans, in various projects for the restoration of territories. Tasks related to this process can be very diverse, including reconstruction of infrastructure, construction of new facilities, restoration of natural resources, and others. Because such tasks can have complexity and interdependencies, it is important to have a tool that can help manage all projects as a whole.

In addition, an intelligent system can provide interaction between different teams and stakeholders, which will help ensure cooperation and coordination of work at all levels. In addition, it can provide access to a variety of information for all participants in the process, which can improve communication and reduce errors.

All these factors make the developed system indispensable for recovering the territories of Ukraine after Russia's armed aggression. This tool can ensure optimal coordination of various projects and make recovering of territories more efficient and faster. The condition of its application is the need for the information standard of the company that will implement the system, in order to obtain statistical information for planning and monitoring of new projects. In practice, the use of this system gives the company an «electronic expert assistant»

capable of planning and monitoring projects in the process of direct interaction with project team members.

The previous version of the system has already passed practical testing for development projects in Ukraine. These are projects for the construction of a shopping and entertainment complex, a recreation center and a logistics center. As shown by experiments and practical testing of the system, setting the system to a new language takes about 1 hour and consists both in the automatic translation of address templates and in minor adjustment of the structures of expressions to the features of the new language.

In contrast to traditional approaches [15–21], which are based on the use of neural network technologies or linguistic processors, the proposed approach allows with minimal costs to configure the system to use a new language without losing the effectiveness of its functioning. It was the proposed approach that made it possible to solve the main problem of the work – to create a multilingual intelligent project planning and monitoring system.

The limitations of the study are the need to develop new structures of statements, while expanding the functions of project management (not only for planning and monitoring).

The shortcoming of the study is that the functions of setting up and administering the project planning and monitoring environment in instrumental software were not considered in the study. In addition, the module for transferring project planning and monitoring actions from MIPPMS to some instrumental project management system (MS Project, Oracle Primavera P6, etc.) has not been implemented.

In the future, it is planned to develop the research data for other functions of project management, for example, management of procurements, risks, finances. Such development will allow creating digital project management in the full sense. And eliminate the person with its mistakes and inability to process large volumes of information with high quality from the project management circuit as much as possible.

7. Conclusions

1. A model of information interaction of managers and specialists engaged in the processes of project planning and monitoring has been developed. The peculiarity of the model is that the planning process is considered not as a functional process, but as a process of information interaction between the team and the project planner. This allows to plan projects based on the statements of project team members, independent of the language of communication, based on the development of reflexes on elements of natural language. The construction of such a model requires much less efforts for the creation of project management systems as well as for project planning.

2. An analysis of the structure of natural language statements, which reflect the interaction of teams with project planners, was performed. Obtaining a set of templates that reflect such structures makes it possible to discretize the process of information interaction between team members and the project planner, which in turn allows creating a multilingual intelligent project planning and monitoring system. A total of 188 such structures have been developed.

3. A reflexive method of processing natural language information regarding project planning and monitoring has been developed. The basis of the method is the calculation of the amount of informational influence of the elements of statements on the MIPPMS reaction, which is based on the deviation of the conditional probability of a certain reaction to the element of the statement from the unconditional one. Therefore, this method is much simpler than linguistic analysis methods or neural network methods. It does not require the creation of thesauruses, nor the training of a neural network in a specific language, nor methods of pattern recognition. Therefore, it is faster, simpler, and its result corresponds to the influence of the content of the statement on the planning and monitoring process.

4. A method of experimental research has been developed to evaluate the effectiveness of MIPPMS in processing language-independent natural language information for project planning and monitoring. This technique is designed to experimentally test the multilingual system, to determine the differences between the effectiveness of planning and monitoring in different languages. That is why it differs from others and allows a qualitative assessment of MIPPMS.

5. Experimental studies have been conducted, the feature of which is the synchronization of the calculation of informational influences for statements in different languages to achieve the goal of the study. It is shown that the reflective intelligent system is easily configured (no more than 1 hour) and effectively plans and monitors projects. The probability of correct responses in project planning and monitoring is 0.98–0.99.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, including financial, personal, authorship or other, which could affect the research and its results presented in this article.

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Data availability

The manuscript has data included as electronic supplementary material.
Data will be provided upon reasonable request.

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