METHODICAL APPROACH TO FORESIGHT-RESEARCH AT DEFINITION OF TRENDS IN GREEN IT DEVELOPMENT

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Abstract: The problem of determining the Green IT development strategy using decision support tools is described in the article. Technology Green IT is a typical result of the advanced technologies convergence, especially information and knowledge. The expediency of the foresight technology applying for the Green IT development perspective directions evaluating is shown. It is indicated that the most critical, in this case, is the stage of forming the initial list of directions. The technology of retrospective analysis of the Green IT development based on the parametric synthesis of the predictive model of exponential smoothing under the conditions of data uncertainty is presented. For the implementation of the parametric analysis of Brown's predictive model, or exponential smoothing, is used the exponential average value of the stationary time series to evaluate its value at the next time point. The applying of the developed technology provides experts with additional volumes of information about the perspectives for the Green IT development. An example of a retrospective analysis of the Green IT development directions is given. The initial data for the retrospective analysis used the number of scientific publications for the period from 2010 to 2015 in Ukraine, which characterizes the Green IT direction development. The following directions were assessed: green software engineering, software ecosystem, energy-saving green software and green telecommunications. As a result, the most promising direction is green software engineering. The results of the analysis are one of the sources of information for assessing the perspectives for the Green IT development directions by experts.

Keywords: green IT, technologies, foresight, retrospective, exponential, Brown, time series, structural, parametric, trend.

1. Introduction

At the moment, one of the stable trends of human development is the development and introduction of Green IT to solve problems that are related to energy conservation [1–3]. Technology Green IT is a typical result of the advanced technologies convergence, especially information and knowledge ones [4, 5]. However, determining the Green IT development strategy is a rather complicated process, which is characterized by high levels of uncertainty. At the same time, the process of forming the initial list of Green IT directions development is one of the uncertainty main sources. In connection with this circumstance suggested to use the methods of retrospective analysis to reduce the level of uncertainty in the decision making process when evaluating areas of Green IT.

Today, progressive technology for determining of the Green IT development strategy is foresight technology [6]. In this technology, the most critical stage is the formation of the initial list of directions for the development of the Green IT, since at this stage experts face a high level of uncertainty arising from the deficit of relevant information in the formation of decisions.

The purpose of the article is describing the approach to improving foresight technology by supplementing it with special means of supporting decision-making by experts to reduce the level of uncertainty at the stage of forming the initial list of Green IT development directions.

2. Methods

As a source data, a list of indicators (parameters) characterizing the Green IT development directions is used.

Problem solving process is regulated by the second stage of foresight research, namely by evaluating the Green IT development directions according to the specified criteria. One way to solve the above problem is to supplement foresight technology with special retrospective analysis tools that expand the basis of the argumentation when experts make decisions to determine the direction of Green IT development.

As a result of solving the problem will be obtained an updated list of Green IT directions development.

The technology of carrying out the foresight-research consists of the following steps [7]:

1. Formation of expert panels, i. e., number and structure of expert members participating in forecasting based on the evaluation of their competence level.

2. Forming the initial list of the Green IT directions. It is necessary to analyze the status and perspectives of Green IT development using methods of bibliometrics (calculating the number of publications), scientometrics (analysis of citing) and patent analysis (trace analysis of the dynamics of inventive activity). Then, for obtained the lists of Green IT development directions it is calculated the value of criteria for their assessment provided by technique of foresight-researches. Thus, all "leading" directions have quantitative assessments for each of the criteria, which will help to determine the number of priority.

3. Selection of priority directions for Green IT development. Initial data for the selecting of priorities is a list of Green IT directions, as well as a set of values of criteria assessment for each direction. The procedure for the selection of Green IT priority directions development is in ranking these directions criteria using the Pareto optimality principle and t-ordering method.

4. Coordination and approval of Green IT priority directions. In accordance with the current technique, the strictly regulated procedure for coordination and approval of Green IT priority directions development is carried out.

At the second stage of foresight technology to support experts in the course of their decision-making, it is suggested to use a retrospective analysis of time series characterizing the development indicators of Green IT directions.

The solution of the formulated problem involves the using of parametric synthesis methods for the predictive model of exponential smoothing under conditions of data uncertainty and complexation methods of forecast estimates.

To predict the Green IT development, it is proposed to use Brown's adaptive predictive model [8]. The application of the parametric identification method of Brown model according to the results of a retrospective analysis of the Green IT development, which, unlike the known ones, is based on the analysis of the configuration of retrospective equations roots, will allow analytically to determine the parameters of the model setting that ensure the accuracy of predictive estimates. The adequacy of the predictive model of the Green IT development

is provided through the implementation of the structural-parametric synthesis method, which takes into account the particularities of the type of source data used [9].

For the implementation of a parametric analysis of Brown's predictive model, or exponential smoothing, is used the exponential average value of the stationary time series to evaluate its value at the next time point:

$$\hat{y}_t = \alpha y_{t-1} + \alpha(1-\alpha)y_{t-2} + \ldots + \\ + \alpha(1-\alpha)^{n-1} y_{t-n} = \sum_{i=1}^{n} \alpha(1-\alpha)^{i-1} y_{t-i}, \quad (1)$$

where $y_{t-1}, y_{t-2}, \ldots, y_{t-n}$ – the value of the series at the corresponding moments of time; n – sample length of the time series; α – smoothing parameter.

The quality of the retrospective forecast estimates obtained for the time series values in the past relative to the t points of time have tends to be preserved at a later point in time. For the a posteriori solution of the parametric synthesis problem, it is necessary to form retrospective equations of this kind:

$$\varepsilon_{t-1}(\alpha) = 100 \cdot \frac{\hat{y}_{t-1}(\alpha) - y_{t-1}}{y_{t-1}} = \\ = \frac{100}{y_{t-1}} \cdot \left(\sum_{i=1}^{n-1} \alpha(1-\alpha)^{i-1} y_{t-i-1} - y_{t-1} \right) = 0. \quad (2)$$

Using this method, it is possible to analyse the time series of two types: numeric and interval.

The method of structural-parametric synthesis contains the identification of the time series, which includes a preliminary analysis and processing of output data, namely the allocation of the trend and the formation a number of interval residues [10].

On the basis of identification, one or more interval retrospective equations should be formed. In order to establish the fact of finding the roots of the interval polynomial in the range $0 \le \alpha \le 2$, it is proposed to use a bilinear transform of the form

$$\alpha = \frac{2}{1+w}, \quad (3)$$

which represents a single circle with centre at the point (0; 1) in the plane of the parameter α in the right half-plane of the complex plane.

3. Results

As a starting point for retrospective analysis, a list of indicators characterizing the Green IT directions development in Ukraine was used, namely: the number of scientific publications for the period from 2010 to 2015 years (**Table 1**). Using the method of the parametric identification of the Brown's Model for the creation of the Green IT, the following directions were assessed: green software engineering, software ecosystem, energy-saving green software and green telecommunications.

The results of a retrospective analysis in the direction of Green software engineering are shown in **Fig. 1.** Thus, a retrospective analysis of the direction of development of Green IT was conducted and it was found that the smallest perspective, in the future, has a direction of the software ecosystem, and the largest – green software engineering.

Table 1

Distribution of scientific publications in the Green IT directions for 2010–2017 years

No.	Direction	Number of scientific papers (articles, abstracts and books), pcs									Specific weight in the total number of publications, %
		2010	2011	2012	2013	2014	2015	2016	2017	Total	
1	Energy-saving green software	8	7	12	25	18	17	20	18	125	26
2	Green software engineering	5	11	16	18	27	35	38	43	193	40
3	Software ecosystem	6	6	11	8	10	10	18	15	84	17
4	Development of green telecommunications	5	10	10	13	12	14	12	10	86	18
	Total	24	34	49	64	67	76	88	86	488	100

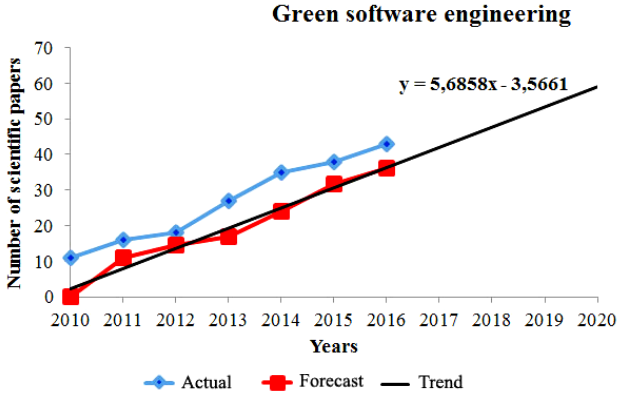

Fig. 1. The retrospective analysis results of the direction "Green software engineering" by the evaluation criterion "Number of scientific papers"

4. Discussion

It is proposed to improve the technology of foresight research for determine the Green IT development by completing the second stage of foresight "Forming the initial list of the Green IT directions" by parametric synthesis methods of the exponential smoothing predictive model under uncertainty of data.

The applying of the retrospective analysis of the Green IT development provides the formation of an additional information source for experts assessing the perspectives of the Green IT development directions in the second stage of the foresight research.

In the course of the research it was established that the use of Brown's predictive model in implementing of parametric analysis of time series members is not effective enough. Using the method of two-parameter exponential smoothing makes it possible to improve the quality of retrospective predictive estimates of the time series due to easing of constraints in solving the problem of time series analysis.

The implementation of the proposed approach is illustrated by the example of a retrospective analysis of time series of certain criteria for assessing the direction of Green IT (the number

of publications) in Ukraine. The applying of the described approach made it possible to determine the development dynamics of these directions. Obviously, the most stable and significant dynamics is observed in the direction of "Green software engineering", because the share of its publications is 40 %. The rates of its pronounced linear growth are at least twice as high as in other directions (y=5.6858x–3.5661). The rates of its pronounced linear growth are at least twice as high as in other directions (y=5.6858x–3.5661). The directions of the weakest dynamics, according to the trendline equations, are the directions "Development of green telecommunications" y=1.6881x+1.5061 and "Software ecosystem" y=1.3573x+3.3222, which indicates a decrease in the number of publications. Thus, the most promising direction in Ukraine is "Green software engineering".

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