UDC 004.415:001.89 **DOI:** 10.31673/2412-9070.2025.061214
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ARCHITECTURE OF THE SOFTWARE SYSTEM FOR EVALUATING THE LEVEL OF INTERNATIONALIZATION OF THE SCIENTIFIC INSTITUTIONS

The article presents the development of a basic architecture of a software system designed to evaluate the level of internationalization of scientific institutions. The need for such a system arises due to the growing importance of internationalization in scientific activity and the lack of standardized software tools that support this process. Developed on the basis of a generalized process model, the proposed architecture meets the key functional requirements for the software system and ensures the implementation of the main use cases of all users, including experts from the executive group, experts from the community of stakeholders, managers of institutions and public users. The architecture consists of four main modules: design of the valuation system, construction and selection of methodologies, conducting computational valuations and publication of results.

The proposed approach simplifies the development of software systems to support decision-making based on adequate and substantiated processing and analysis of indicators of international scientific cooperation and competitiveness for heads of scientific institutions and other stakeholders.

Keywords: internationalization of scientific institutions; evaluation of the level of internationalization;, architecture of the software system; software engineering

Introduction

The concept of internationalization of scientific activity emerged as a multi-level social reaction to the globalization of the world economy, because involvement in the international scientific process is seen as access to new knowledge, means of obtaining it and to the latest technologies - everything that contributes to the successful development of the economy of countries, and therefore to solving social problems.

Due to the variety of interpretations of the concept of internationalization of scientific activity, evaluating its level poses a certain problem [1-4]. A generalized model of the process of evaluating the level of internationalization, aimed at preventing this problem, is given in [5].

Despite the fact that evaluating the level of productivity of scientific institutions has been known for a long time, for example, in the form of rating systems such as ARWU, THE WUR, SCImago or CWTS Leiden Ranking [6-9], today there is no single approach to developing software systems for evaluating the level of internationalization of scientific institutions, which causes the absence of appropriate software systems. Therefore, it is advisable to direct research in the field of software engineering to the development of basic architectures to simplify the process of developing software for evaluating the level of internationalization of scientific institutions. The purpose of this study is to develop a basic software architecture for evaluating the level of internationalization of scientific institutions based on the process model [5].

Requirements for a software system for automating the process of evaluating the level of internationalization of a scientific institution

Developing a software system for automating the evaluation process requires, first of all, determining the requirements for it [10-12]. This study does not specify such substantive aspects as

the policy and strategy of internationalization of scientific institutions, current legislation, etc. Therefore, only the functional requirements for the software system are considered here.

Functional requirements provide for the provision and support of the main processes that require automation when building a system for evaluating the level of internationalization. As follows from the analysis presented in [5], these are such processes as:

- designing a system for evaluating the level of internationalization of a scientific institution;
- researching the evaluation system;
- adopting one of the specified evaluation methodologies of the Level of Internationalization of Research and Scientific Institutions (LI RSI), if it meets the quality criteria as an approved specification of the evaluation system;
- using the approved specification of the LI RSI evaluation system to evaluate the level of internationalization;
- publishing the evaluation results.

When defining the boundaries of the system, it turned out to be appropriate to distinguish four areas of the software system: Executive Expert Group Area, Stakeholders Community Area, Institution Management Area and Public Area (Figure 1).

The information environment, which contains resources external to the system with actors with the "support_actor" stereotype, as well as the operational environment in which the software system operates, is schematically represented in Figure 1 by one element with a dotted perimeter.

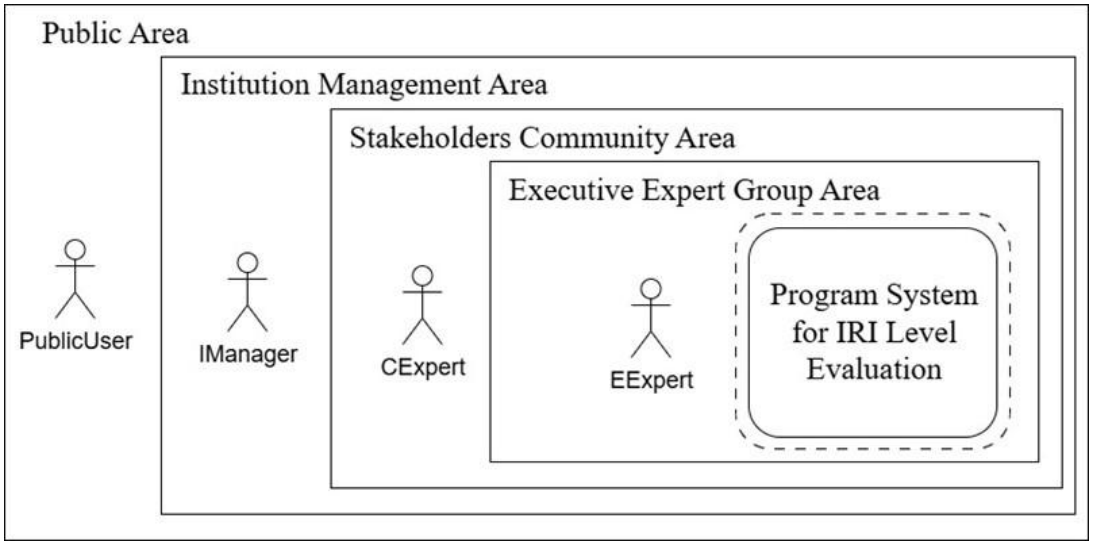

Fig. 1. System boundaries

Actors symbolizing users from each area presented in Figure 2 are:

- expert EExpert – a user from the Executive Expert Group Area responsible for creating and agreeing on the methodology (methodology, calculation method) of the internationalization level, approving the specification, performing the evaluation of the internationalization level in accordance with the current specification and publishing the evaluation results;
- expert CExpert – a user from the Stakeholders Community Area has advisory powers at all stages of seeking consensus between the Executive Expert Group and the Stakeholders Community on the methodology for evaluating the internationalization level;
- manager IManager – a user from the Institution Management Area is an employee of a scientific institution. Like any user, he can view the published current evaluation methodology and, in fact, the evaluation results. But, in addition, IManager can perform a test evaluation on test data. Test data is any data that differs from the actual data. The purpose of the test evaluation is to determine what the evaluation results would be if the indices (indicators) of his or other institutions had different – higher or lower values than those that were actually achieved;
- user PublicUser – a user from the Public Area that can view the published current evaluation methodology and evaluation results.

The use case diagram in Figure 3 gives an idea of the use of the software system by its users.

The “View Results” use case assumes that all users Users can view the results of the evaluation of the level of internationalization of scientific institutions in tabular, graphical form, as well as a description of the approved methodology (specification). For a public user, this is the only one use case.

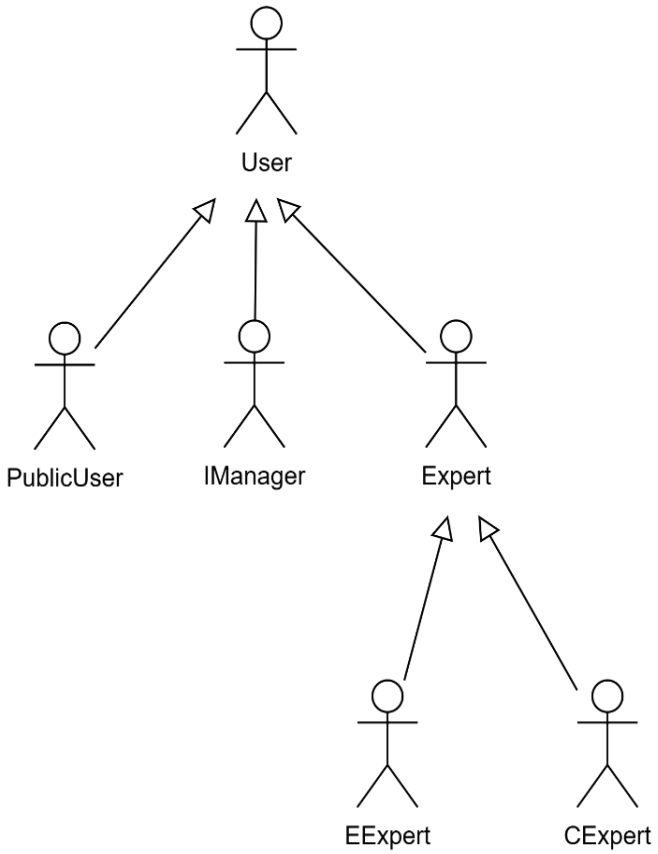

Fig. 2. Software system users

The “View test data” use case extends “View Results” and provides editing of test data and viewing of results, after recalculating the level of internationalization on them. This use case is available to all Experts and the manager of the scientific institution IManager.

An expert of the executive expert group EExpert designs the evaluation system in the “Designing an IRI evaluation” use case. This use case assumes the creation of alternative methodologies, for each of which the dimensions of the evaluation of the level of internationalization, the set of indices for determining each of the dimensions, the methods of normalization and aggregation of indices, and the method of aggregation of dimensions are selected.

The design is carried out taking into account the requirements and limitations of the current internationalization strategy and policy, which is represented in the diagram in the form of the actor “Internationalization Strategy & Policy” with the stereotype “support_actor”.

The “Study of IRI evaluation” use case involves specifying each of the methodologies and evaluating their quality according to the quality criteria represented in the diagram by the support actor “IRI-level evaluation quality criteria” with the stereotype “support_actor”.

Conclusions about the quality level of the methodology and the selection of the methodology with the highest quality indicators are made by EExpert experts, taking into account the opinion of CExpert, within the “Quality Control” use case, which is in the <<include>> relation to the “Study of IRI evaluation” precedent.

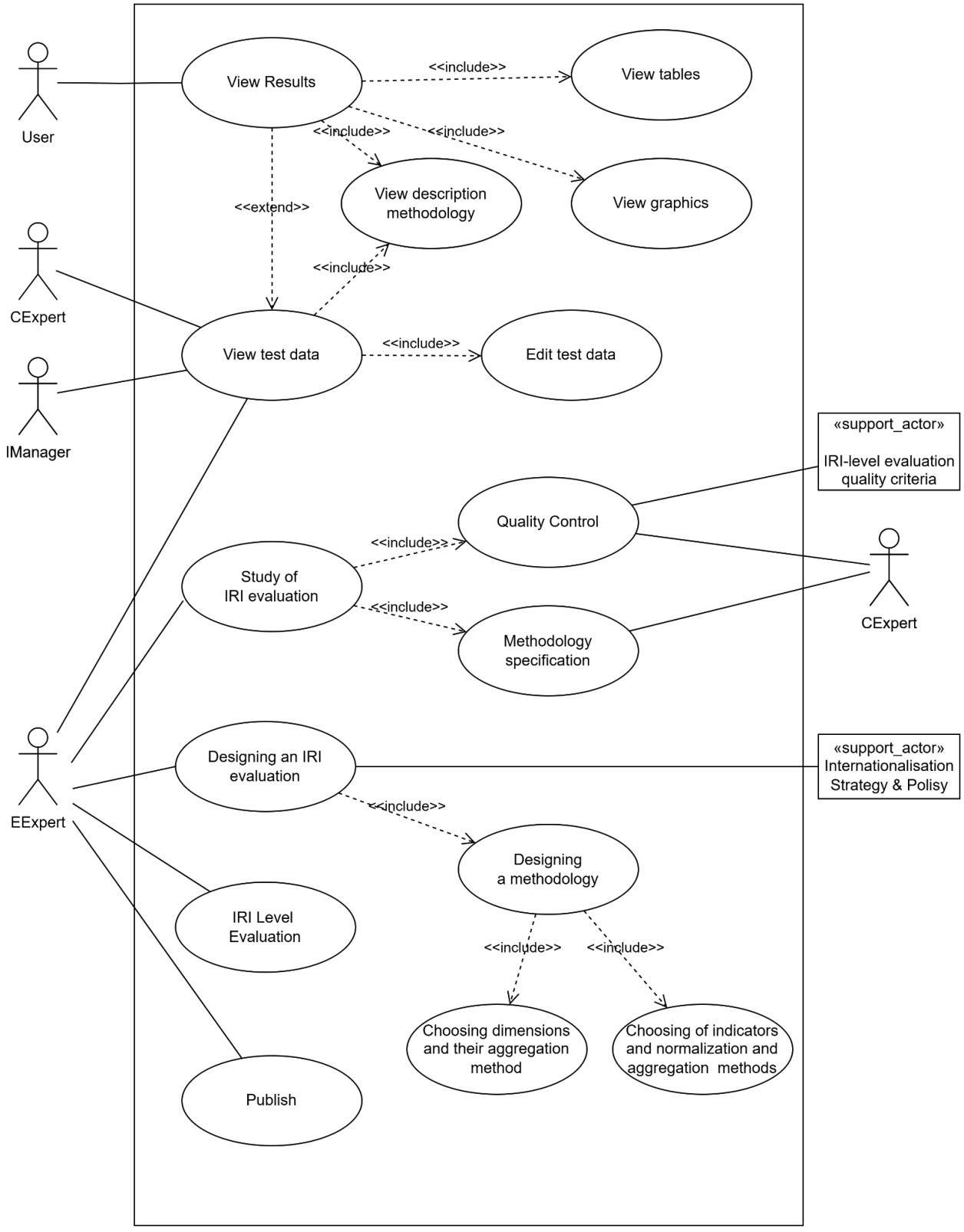

Fig. 3. Use case diagram

The user of the EExpert software system can perform an evaluation of the level of internationalization, the “IRI Level Evaluation” precedent, in accordance with the approved specification.

The “Publish” precedent ensures the publication by the EExpert expert of the results of the evaluation of the level of internationalization of scientific institutions and the approved methodology for such evaluation.

Basic architecture and software components of a software system for automating the process of evaluating the level of internationalization

Given the specified requirements for the software system for automating the process of evaluating the level of internationalization and the features of the process itself, it is possible to determine the basic architecture of the software system, as shown in Figure 3.

The proposed architecture corresponds to the structure of the evaluation process and the main identified options for using the system and provides for the following logic of the software system functioning.

At the initial stage - the stage of designing the evaluation system, the expert of the executive group (EExpert) selects dimensions and a set of indices (indicators) to determine each of the dimensions, methods of normalization and aggregation of indices, as well as the method of aggregation of dimensions. Due to the impossibility of unambiguously selecting indicators that would reflect the level of internationalization, the EExpert can perform such a selection by repeatedly creating several options for a partially defined methodology (Methodology) for further work with them to select the best one. The set of created methodologies makes up the Project composite, which is the main artifact at this stage.

In addition to the name, creation date and other identification data, the Project artifact also has the “Status” property to indicate its status. This property can take one value from an agreed list, such as “Created”, “Draft”, “In Progress”, “Under Review”, “Approved”, “Obsolete” etc.

Similarly, each methodology defined within the Project, in addition to a short description and identification data, also contains a similar property (parameter, record) “Status”, among the values of which should be the values “Specified” and “Approved Specification”.

The specification is a declarative form of one specific set of actions (scenario) of evaluating the level of internationalization, which must be performed by the software system. Since the number of various scenarios is practically infinite, the definition of a specific methodology requires, first of all, the name of a specific software method capable of implementing such a scenario. Each specific software method may require a unique set of parameters that must be specified in the methodology, therefore, the set of data specified in the methodology, generally speaking, does not require standardization - the specified specific software method requires them.

Any difference in calculating the level of internationalization involves the creation of a separate methodology. Let, for example, on the same data with identical sets of data sets, measurements and methods of weighting and aggregation, but, for example, with data normalization by the min-max methods, z-score and mean normalization. Then three methodologies should be created with a declaration of the corresponding normalization methods.

At the first stage of design, the methodology may be only partially defined, and then it has the status "Draft" or another status preceding the "Defined" status.

All metadata, data and artifacts, except for published materials, are stored in the Data Store cloud environment.

At the next stage, the expert of the executive group (EExpert) performs additional definition (specification) of the methodologies, after which the methodology receives the status “Specified”. Each methodology with the status “Specified” can be used to calculate the level of internationallyzation, which allows choosing from them the one that most fully satisfies the quality criteria. The expert of the community of stakeholders CExpert also participates in the process of selecting the best methodology. The specified methodology selected in this way receives the status “Approved Specification” and becomes the main artifact of this stage. In the process of studying methodologies for compliance with quality criteria, certain formal and expert procedures are performed, including the evaluation of the level of internationalization.

The next stage is the stage of evaluation (calculation) of the level of internationalization of scientific institutions according to the specification, initiated by the EExpert expert, and the results are stored in the cloud environment.

The stage of publication of results involves the generation and publication of a description of the methodology, under this name and in a readable form, the public user knows the “Specification”, as well as the publication of results in tabular and graphical forms. At this stage, a special publication mode is also available - together with test data, which can be edited by the manager of the scientific institution and re-evaluated. Edited data is not saved, i.e. it exists during one session of IManager. Work with test data is available to all users, except the public user PublicUser.

This logic of work corresponds to the proposed basic architecture. As can be seen from Figure 3, the basic architecture contains four main modules: “Design an evaluate system”, “Methodology construction”, "Perform computations" and “Publication of results”.

The “Design an evaluate system” module implements the functionality of the software system in terms of forming the primary artifact – the Project project, which contains unspecified variants of the evaluation methodology Methodology. Forming an unspecified variant of the methodology involves the selection of dimensions, sets of indicators, normalization and aggregation methods, but, possibly, without specifying some parameters that will be specified later. The module contains two components – “Design an assessment structure” and “Index system design”.

The created Project artifact is stored in the Data Store cloud environment. In Figure 4, all artifacts that are saved or read from the Data Store are highlighted in color and provided with a comment.

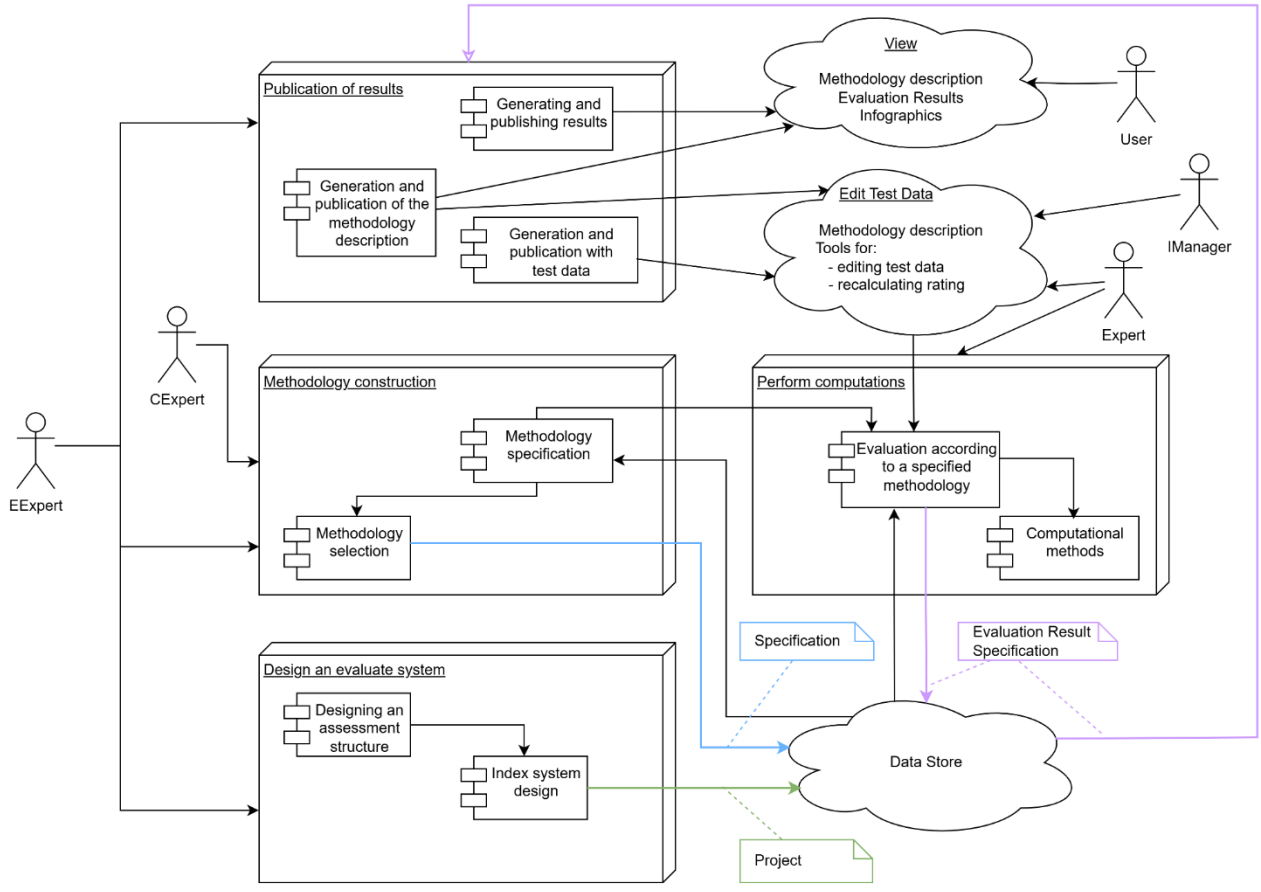

Fig. 4. Basic architecture of a software system for automating the evaluation of the level of internationalization

The “Methodology Construction” module contains two components – “Methodology specification” and “Methodology selection”, the first of which reads the Project from the data warehouse, specifies each of the methodologies, and refers to the "Perform computations" module to perform the necessary procedures according to the specified methodology. The “Methodology selection” component ensures the creation of the Specification artifact and stores it in the cloud storage.

The "Perform computations" module ensures the execution of all necessary computational procedures, such as performing an evaluation or conducting statistical tests. It consists of two compo-

nents – "Evaluation according to the specified methodology" and "Computational methods". The module and both of its components implement the necessary computational methods required both at the stage of creating the specification and at the stage of its use.

The "Publication of results" module includes three components – "Generation and publication of the methodology description", "Generation and publication results" and "Generation and publication with test data".

The proposed architecture of the software system for automating the process of evaluating the level of internationalization is basic, which means that it can be adapted to the needs of communities of scientific institutions.

Conclusion

The results presented in this article regarding the process of designing software to automate activities aimed at evaluating the level of internationalization of scientific institutions allow us to formulate the following conclusions:

1. Functional requirements for a software system for automating the process of evaluating the level of internationalization were identified by identifying the main actors and use cases of the system. This definition is based on the results of modeling the evaluation process presented in [5].

2. The basic architecture of a software system for automating the evaluation of the level of internationalization is proposed, which contains a universal set of modules and components that ensure the implementation of the main use cases. When developing a specific software system, the basic architecture can be adapted to the needs of a specific scientific community.

3. All the results presented in this article are aimed at simplifying the process of developing software for the needs of managing the level of internationalization of scientific institutions of a specific community.

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АРХІТЕКТУРА ПРОГРАМНОЇ СИСТЕМИ ОЦІНЮВАННЯ РІВНЯ ІНТЕРНАЦІОНАЛІЗАЦІЇ НАУКОВИХ ІНСТИТУЦІЙ

У статті представлено розробку базової архітектури програмної системи, призначеної для оцінки рівня інтернаціоналізації наукових установ. Потреба у такій системі виникає через зростання значення інтернаціоналізації у науковій діяльності та відсутність стандартизованих програмних інструментів, що підтримують цей процес. Розроблена на основі узагальненої моделі процесу, запропонована архітектура відповідає ключовим функціональним вимогам до програмної системи та забезпечує реалізацію основних варіантів використання усіх користувачів, включаючи експертів виконавчої групи, експертів спільноти зацікавлених сторін, менеджерів установ та публічних користувачів. Архітектура складається з чотирьох основних модулів: проєктування системи оцінювання, побудова та вибір методологій, проведення обчислювальних оцінок та публікація результатів. Кожен модуль містить компоненти, що забезпечують повну функціональність системи на всіх етапах процесу оцінювання інтернаціоналізації.

Запропонована архітектура підтримує створення та вдосконалення методологій, вибір вимірів та показників оцінювання, проведення оцінок якості та розрахунок рівнів інтернаціоналізації з використанням тестових та реальних даних. Передбачається публікація результатів у зручних для користувача форматах, включаючи таблиці та візуалізації. Менеджери установ можуть виконувати гіпотетичні оцінки, використовуючи редаговані тестові дані для дослідження сценаріїв покращення. Усі дані та артефакти зберігаються у хмарному середовищі для забезпечення доступності та безпеки.

Розроблена архітектура задумана як універсальна основа, яку можна адаптувати до конкретних потреб різних наукових спільнот та стратегій інтернаціоналізації. Це підвищує прозорість, ефективність та стандартизацію оцінок інтернаціоналізації. Робота робить внесок у спрощення розробки програмного забезпечення шляхом адаптації до потреб конкретної спільноти запропонованого універсального набору модулів. Такий підхід дозволяє спростити розробку програмних систем для підтримки прийняття рішень на основі адекватних та обґрунтованих обробки, та аналізу показників міжнародної наукової співпраці, та конкурентоспроможності для керівників наукових установ, та інших зацікавлених сторін.

Ключові слова: інтернаціоналізація діяльності наукових інституцій; оцінювання рівня інтернаціоналізації; архітектура програмної системи; інженерія програмного забезпечення.