



## The electronic library: using technology to measure and support Open Science

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### **Abstract:**

*Open Science is a modern vision of the near future of research practice based on advanced electronic library (EL) technology that: (a) gives individual researchers better tools to shape and share research results with Society, (b) creates a more efficient scientific circulation mechanism, and (c) provides improved measurement of research results usage/impact. In the paper we present an approach to designing an EL environment that can satisfy these Open Science challenges. The proposed approach is based on a concept of scientific objects-for-reuse that circulate throughout a research community by a mechanism specially designed to improve their scientific usage and to collect quality data about usage characteristics. This is achieved by development of EL tools, by establishment of research data and information spaces (DIS) and by implementing online research infrastructure at the national level. Currently in Russia the approach has a pilot implementation called the Socionet. We expect essential benefits and clear added value by integrating this approach with a national research assessment information system aimed to improve evaluation of researchers and scientific organizations.*

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### **Introduction**

Open Science is a modern vision of the near future of research practice based on advanced electronic library (EL) technology that: (a) gives individual researchers better tools to shape and share research results with Society, (b) creates a more efficient scientific circulation mechanism, and (c) provides improved measurement of research results usage/impact (Parinov 2009).

A shift from the current system to Open Science provides various improvements of the research environment. We expect three new features:

- Better representation of research output/results as computer-readable information objects of modern electronic research environment.

A research article as the current primary form of research results representation has shortcomings, e.g. a weak digital structuring of different parts of one article that

used (or can be used) by research community, no computer-readable data on how it was used, about scientific inference relations between them, etc.;

- Better scientific circulation of research outputs/results.  
The current circulation mechanism based on the scientific journals system has well-known shortcomings such as restricted access to research, distribution delays, lack of transparency in the reviewing process. and often not predictable decisions on publishing papers, etc.;
- Better measurement of how Society uses research outputs/results.  
The current citation index as a basic indicator of research performance does not consider variations in types of cited scientific objects and in types of usage by research community.

Implementation of such improvements means essential changes for the research community and, of course, it will take a lot of resources. It also needs real motivations for researchers to learn and use new tools, to change their research practice.

However there are strong driving forces supporting evolution of current research practice to the Open Science model. The research community will benefit with better representation of research results, more efficient circulation of ideas, more precise perceptions of produced research results including how and by whom new scientific knowledge is created. More important that research assessment programs existed in many countries, and now in Russia, will also benefit by shifting to the Open Science research practice, since they will be able to use new quality data for evaluation of researchers and organizations instead of not transparent and often not predictable evaluation results produced by expert panels. So if research assessment program will mandate scientist to use new EL technology that will create necessary motivations for using new tools and changing research practice.

Establishing an approach to measure and support Open Science and taking into account the expected features we should have answers to the following general questions:

- 1) How should we organize within EL environment a process of research outputs/results usage, and design necessary metrics and tools to provide maximally comprehensive and accurate statistics on the uptake, usage and impact of research results?
- 2) How should we construct an EL technology for shaping and sharing research outputs/results of individual researchers stored at institutional EL and/or IR so as to provide efficient circulation and necessary conditions for its maximal usage by Society?
- 3) How should the data and information space (DIS) of research outputs/results and research e-infrastructure accumulate and process statistics to generate new online metrics sufficient for research assessment of higher quality, sensitivity, breadth, accuracy, reliability, and validity than current metrics?

According current Socionet system background (<http://socionet.ru/>, in Russian) developed last 10 years we formulated specific responses to listed questions as a concept of research EL environment and now we are developing its pilot version which should demonstrate a new way of research outputs/results sharing and circulation, measuring the impact and research performance, including new and improved scientometric indices and evaluation criteria. Thus EL environment has following main features:

- a) A specially designed circulation mechanism for research outputs/results, which complement a current one based on scientific journals' system. The new mechanism aims at compensating for the different shortcomings of the current system, including the creation of better competition among similar research results to be used by society and cited by scientists.
- b) A special electronic presentation of research outputs/results as objects-for-reuse, designed to efficiently circulate and to provide improved conditions for its usage.

c) The new circulation mechanism harvests research outputs/results provided by individual researchers at their IRs and represent them as integrated research DIS.

d) New metrics and tools of usage for circulating objects-for-reuse designed to ensure accurate measure of the differences in qualitative and quantitative usage characteristics.

e) Automatic services to trace changes in DIS and accumulate scientometric statistics. The statistics are processed to build impact and performance indices of research, researchers, research projects and organizations.

f) Scientometrics to implement new incentive and motivation schemes for researchers based on new impact and performance indices of research, researchers, research projects and organizations to complement and improve the traditional incentive structure.

The Socionet system as a technical background for this approach is described in the next section. Then we discuss three main Open Science challenges: (1) scientific objects-for-reuse concept, (2) scientific circulation mechanism, (3) generated statistics, scientometrics and based on it research assessment. As a conclusion we are discussing possible Open Science benefits for quality improvements within research evaluation practice.

### **Electronic Library Technology at Socionet**

The Socionet system development was started in 1997 as a Russian Virtual Laboratory for Economists and Sociologists project. At the beginning it provides a mirror of RePEc.org data and functionality. It also included the first in Russia scientific open archive to submit research papers in Social Sciences for its online presenting, and some simple tools of virtual workspace (Krichel & Parinov 2002).

In 2000 the designed information system got the new name "Socionet" (socionet.ru), since from that time it has own harvester, which federates more research collections and archives, than RePEc provided (Parinov et al. 2003). It allowed building and, from that time, everyday updating the Russian research information space for Social Sciences (it was the first release of research DIS in Russia).

In 2002 a Socionet Personal Zone was created as add-in online workbench and a management system for academic electronic assets. It allowed a management of electronic collections for 9 data types (e.g. "person", "institution", "paper", "article", "book", etc.). The Personal Zone also included software of the "personal information robot" to trace new additions/changes within DIS according personal research interests of users and notify them about relevant findings (Parinov & Krichel 2004).

In 2004 Socionet users got some new tools to create and manage semantic linkages between information objects of DIS. From that time some information objects in Socionet, like personal and organizational profiles can represent professional social networks of appropriate research players (Parinov & Krichel 2004).

In 2007 monitoring of DIS changes and statistics automated services were run. The Socionet scientometric database has been accumulating from 2007.01.01. The Socionet statistics section provides a big set of time series indexes. It includes indexes of views/downloads aggregated according linkages between DIS information objects, e.g. a sum of views/downloads for all publications linked with a personal profile, or the next step of aggregation – a sum of personal indexes for all people linked with an organization's profile, and so on (Kogalovsky & Parinov 2008).

In 2009-2010 the Socionet users got new services to create and manage objects-for-reuse collections, including implemented model of electronic citations with quality attributes (Kogalovsky & Parinov 2008). The monitoring service of the Socionet now can trace all changes in semantic linkages. Appropriate scientometrics data is adding to the Socionet statistics

database. In combination with a notification system it creates a complete support of "living" documents in the DIS (Kogalovsky & Parinov 2009).

In June 2010 the Socionet system federates more 4000 collections with scientific materials organized on the base of RePEc.org (with about 950000 materials) and 352 collections from Russian research organizations (with about 150000 materials). In total about 4400 repositories are federated as a DIS with currently about 1.1 ml materials and with everyday average surplus of 300 new materials and 1-2 new collections per week. It covers 15 scientific disciplines organized by 16 data types sections.

Currently the Socionet is designed as a virtual multidiscipline research environment that is free available for all types of research players and based on Open Science ideas (Parinov 2009). As an information system it currently includes (only main subsystems listed below):

1. Information hub (IH) is a software unit to federate scientific metadata of IRs, RISs, RePEc archives and from other sources. The IH can harvest local metadata organized in different formats. At IH's output one gets accumulated and daily updated metadata in standardized form. Technically IH's output is designed to fit with software agents and give back metadata through RSS, OAI-PMH and other popular protocols (Parinov 2006).

2. Interdisciplinary research data and information space (DIS) as a visualization of full IH contents presents existed information objects and semantic linkages between them for navigation and searching by Socionet users.

3. Online workbench to create, manage and submit to DIS single materials, whole collections and archives, and also to create/manage networks of semantic linkages between DIS objects. Any researcher or research organization can use it to provide to DIS a proper professional presentation, including objects-for-reuse. Profile of organization with linked collections can be represent as OAI-PMH archive (see 21 Socionet based OAI-PMH archives at <http://roar.eprints.org/view/geoname/geoname=5F2=5FRU.html>).

4. Monitoring and scientometric services, which provides for research community useful scientometric database and notifications. All counted scientometrics indexes are public and can be used for research assessments.

By the initial approach the Socionet is an open EL driven by a research community. Interactions between providers of research materials (scientists and organizations) and the Socionet system are organized on principles of a federation. On June 2010 a research EL environment established by Socionet tools and services was used by about 500 scientists to provide their personal profiles linked with organization's profiles, publications, etc., (about 30000 scientists did similar profiles using RePEc tools). And by about 100 organizations provide their organization's profiles linked with scientists' profiles belonged to their staff, with their thematic collections, etc. (about 11500 organizations' profiles came from RePEc).

### **Scientific objects-for-reuse**

Our response on the first challenge: "How should we organize a process of research outputs/results usage, and design necessary metrics and tools to provide maximally comprehensive and accurate statistics on the uptake, usage and impact of research results?" is a concept of the scientific objects-for-reuse. Similar idea was proposed by LiquidPub project (<http://project.liquidpub.org>) for another purpose, where it was called as Scientific Knowledge Objects - SKO (Giunchiglia & Chenu-Abente 2009).

Typically scientific articles include a variety of text fragments, which are used, or may be used in the future, by scientists to produce a new scientific knowledge and to present it in their own research articles. The cited/quoted text fragments within research articles are only observed facts that some research results were used by Society and exactly by the articles'

authors. A form or a character of its usage often can be recognized only by human experts after reading the article, and such hidden quality characteristics still can not be processed by artificial intelligence software in automated mode. Besides the research results also can be used by research community in latent forms that have no visual representation at all and can not be fixed statistically.

In our approach we define a research results usage as a fact of citing/quoting of a text fragment, which represents the main idea or an essence of the research results and which correctly linked with the source article included that text fragment.

Admittedly, the electronic circulation of research results can be organized more efficiently if the fragments of articles, which may be used (cited) by scientists, will be selected and established as specific objects of electronic research Data and Information Space – DIS (Franklin et al. 2005). Such types of information objects is specially designed for multiple and varied reuse and we called it the scientific objects-for-reuse.

To establish a strong connection between the new scientific objects and the traditional science system the objects-for-reuse can only be a fragment of the published scientific article (or of other type of published scientific material). A full text of the article which is the source for an object-for-reuse should be available in the electronic and/or paper form.

In such cases there is no copyright violation. Since the object-for-reuse completely correspond a typical scientific citation, presents to the public and freely circulate just as a set of metadata (main fields only):

- a) The complete text fragment from a source scientific article/material that is dedicated to be cited (and it means the text is used in some form) in other articles (;
- b) Complete and accurate references to the article-source according with academic rules;
- c) Optional information for easier finding the object-for-reuse, e.g. keywords and scientific classification codes of areas where it can be used, and also terms of usage and recommendations for potential users;
- d) Optional semantic linkages with scientific materials (and/or with another objects-for-reuse) utilized in producing a research result presented by the current object-for-reuse (linked materials can also have another types of relationships with the current objects).

Objects-for-reuse may be created from any publicly available research articles/materials. We called this process as a granularity of research articles (Kogalovsky & Parinov 2009). Objects-for-reuse creation and its inclusion into public scientific circulation can be made by any researcher. It can be done by the author of research article who, by this act, is demonstrating to research community what can be used and cited from his/her article. Also it can be done by just a researcher who would like to share with the community discovered valuable research results within a scientific heritage.

If imagine that objects-for-reuse creation will be a popular activity of research community members, it will produce, at least, following benefits: a) a current corpus of research results in public domain prepared for easy reuse (e.g. as thematic collections available within DIS); b) easy comparative analysis of existed research results in similar scientific areas; c) author's tool to prepare scientific article that integrated with collections of existed objects-for-reuse (filtered for a given article's subject) and gives the author an ability to find and select proper objects for citation and compare them, e.g. by its previous usage characteristics, and so on.

Science system at large will benefit from a stronger competition between similar research results and related objects-for-reuse electable to be cited in articles created by using such author's tool integrated in proposed research EL environment.

Another important benefit can be received if the electronic toolkit for preparing scientific articles (and the objects-for-reuse as well) allows authors to specify quality usage

characteristics for each object-for-reuse selected to be cited in their articles. We called this approach as a model of electronic citations with quality attributes (Parinov 2007).

By research practice the quality characteristics of research results usage typically can vary, e.g., as: (1) the cited research result (or just a citation) is a basement for author's output; (2) the citation approves (or is approved by) author's output; (3) the citation illustrates of (or has another logical connection with) author's output; (4) the citation is wrong or disproved by author's output. This list of options can represent an initial metrics of usage or impact for scientific objects-for-reuse and related research results. The metrics can be changed over time and developed by the research community.

Technically such quality characteristics can be specified as semantic attributes of relations that link a research article with cited in it objects-for-reuse. The semantic attributes of such linkages are stored within metadata of the article and can be correctly recognized and processed automatically by software without human intervention.

The last in the list of objects-for-reuse metadata fields (see above the field "semantic linkages") is also designed to allow a specification of linkages with other objects-for-reuse that can have different types of relations with the current one, including its usage/impact characteristics. So objects-for-reuse itself can have usage type of relations with other objects and produce by this a semantic network of scientific knowledge.

A new research practice based on the proposed approach and associated tools can be fully compatible with the traditional science system. If an author makes a printed version of such article with citation links, the redundant data with semantic characteristics of citation linkages will be automatically removed from the text and the article will have its ordinary format. At the same time, the electronic version of this article will include various linkages with information objects of DIS and represent a node of electronic global network of scientific knowledge.

The scientific objects-for-reuse concept is currently implemented at the Socionet Personal Zone. Socionet users can create and manage collections with type 'citation' that designed specifically for supporting objects-for-reuse features. Electronic collections of scientific objects-for-reuse can be submitted by its owners into public research DIS. It can be included into OAI-PMH institutional repository. While researchers are making an electronic paper, a necessary single object-for-reuse can be found within DIS and/or their personal collections of citations by keywords or scientific classification codes. The object-for-reuse can be electronically cited in the paper's text and its usage quality characteristics can be specified as semantic values of a linkage between the paper and cited object-for-reuse.

### **Scientific circulation mechanism**

Our response on the second challenge: "How should we construct ... a system for shaping and sharing research outputs/results ... to provide efficient circulation and necessary conditions for its maximal usage by society?" is a concept of the scientific circulation mechanism.

It is proposed to build a new complementary mechanism of research results electronic circulation (including objects-for-reuse), which is designing specifically with focus on researchers outputs/results reuse. The mechanism should work in parallel, but independently from the traditional system of scientific publications in peer-reviewed journals, and in a certain way based on it. The new scientific circulation mechanism, in addition to the already existing one, should improve various aspects of the science system that cannot be satisfied in other ways.

Below we discuss only some requirements of the proposed research EL environment important to build well-function scientific circulation mechanism.

All objects-for-reuse, even if they were created in different IRs and other types of research information systems, should be federated within unified research DIS. Integrated electronic catalogues of existed objects-for-reuse should be connected with author's tool to prepare research articles. All existed objects-for-reuse should be available within the electronic citation tool. These features will provide a complete involvement of existed objects-for-reuse in scientific circulation and consequently will create a necessary competition among similar research result to be used and cited in research articles.

Information objects of DIS should be properly presented and organized. We chose a CRIS architecture model (Jeffery & Asserson 2009) and CERIF metadata formats (CERIF 2008) to represent activities and results of research players (scientists, project, organizations, papers, etc). The proper CERIF based representation of research players can be produced by a set of information objects OrgUnits, Persons and Projects in combination with various types of their scientific activities, presented by information objects Publications, Research Results, Events, etc. CERIF Link entity is used as a model to connect all types of information objects and to specify semantic values of linkages (CERIF 2008).

Technical organization of DIS should allow easy creation of semantic linkages (CERIF Semantics 2008) between different types of information objects, including objects-for-reuse. It should be possible to create digital relations that give quality information, e.g. like: objects-for-reuse were used with some quality characteristics; objects-for-reuse belong to an article; some articles have one common author; a project or a research lab has in staff some authors; a research organization supports some projects or labs, and so on. An ability to create semantic linkages in that way will allow: a) getting an aggregate usage/impact picture of research productivity and performance for research players, and b) making a detailed inspection of relations for some results or activities over existed network of linkages and impact characteristics.

All changes/events in DIS should be permanently monitored by software in automated mode. Such services will make just-in-time notification of research players about important events and forms a complete scientometric database about research activities and results. Whereas some kinds of research EL environment monitoring (e.g. changes in DIS scope and structure, information objects' download statistic and so on) are well known and have examples of good implementations (e.g. LogEc; Socionet Stats, MESUR, and other), there is a new area of monitoring, created by so called phenomena of "living" documents (Parinov, 2007) and by intensive development of semantic linkages between information objects.

The basic feature of the proposed research EL environment is a changeable status of all information objects and linkages, including citations. If some citation links were previously established between an article and some objects-for-reuse, which all are in electronic form, the linkages may lose their consistency since the cited object may be changed (this phenomenon is also called "liquid publications" (Casati et al. 2007)). E.g. the cited text fragment may be changed by an author of the article-source for this citation, or this text fragment may disappear or move to another part of the article-source. In all such cases the author of the article that cited changeable text fragments must be informed to make reconsideration all suspicious citations.

To support consistence of research EL environment and fulfill the scientific circulation the monitoring services should notify:

- the author who is changing his/her article, if the article has cited in other articles, that she/he can violate (by this action) links and citations that have established with the changed fragments of the article;

- the authors of articles, if their articles include citation links to the changed article, about a fact of made changes in the cited article, so they should reconsider and, if it necessary, to correct corresponding citations;
- the readers of electronic article that certain citations in reading text can be violated because of the cited articles were changed, and an author of the reading article has not up-dated suspicious citations.

Currently at Socionet the proper DIS is established and within it works necessary monitoring services. We are tracing changes and current conditions of all linkages existed between DIS information objects. In June 2010 about 15000 linkages existed between objects like 'person', 'institution', 'paper', 'citation', etc. were monitored by this way. Automatically accumulated data about linkages are used: a) to build a visualization of DIS structure in a form of a graph and to provide graph navigation tool; b) to search linkages according specified parameters (e.g. by creation/revision date, or by usage characteristics, etc.); c) to create reports for notification system; and etc.

### **Statistics, scientometrics and research assessment**

Our response on the third challenge: "How should the DIS produces and accumulates statistics ..., and how the statistics should be processed to generate new online metrics sufficient for research assessment of higher quality, ... than current metrics?" is a concept of online scientometrics.

On everyday base the automatic monitoring services are tracing information activity of research players within DIS and produce time series statistics about quantitative and qualitative state/changes of research EL environment. The main parts of the statistics are:

a) quantitative characteristics of research players and results of their activity presented by CERIF style information objects "organization units", "projects", "persons", and linked 2nd level objects like "objects-for-reuse/results/publications/patents", "events", "news", etc;

b) quantitative data about all existed relations between information objects, e.g. number of persons linked with organization unit, number of publications linked with a person, number of citations linked with a publication, and so on;

c) qualitative data about all existed relations between information objects, like a graph topology of linkages and semantic values assigned to each edge of the graph, e.g. a set of relations with the semantic value "member of staff" between an organization of unit and persons; a set of relations with the semantic value "basement" between a publication and objects-for-reuse; and so on;

d) data about views/downloads aggregated for each information objects according linkages, e.g. numbers of views/downloads for all publications related with a person or a sum of these numbers for all persons related with an organization unit and so on.

This statistical database should be public and open for external usage. It ensures a transparent and verifiable style of research assessments based on this data.

After some processing the accumulated statistics can represent a useful scientometrics resource, which will illustrate informational activity and results of research players with higher quality, sensitivity, breadth, accuracy, reliability, and validity than current metrics. For example, a scientometric portrait of a researcher will be as follow:

- Personal data or a researcher's profile presented as a complex information object of DIS with existed network of semantic linkages to other information objects (organizations, research results in different forms, events, etc.), including a history of changes of this data.



- Growth characteristics of this complex information objects as time series, e.g. numbers of produced by this person research results (new objects-for-reuse/papers/articles/patents, etc.), and also a numbers of usage facts for the results (like a traditional citation index).
- Usage activity characteristics of a researcher as a number of citations made by the researcher, including a distribution of usage characteristics, which were specified by the researcher as quality attributes of have made citations.
- Usage/impact characteristics for researcher's outputs/results built as a distribution of quality attributes for citations made by other scientists for researcher's materials.

Such public scientometric portrait updated daily in automated mode can be built for each research players of research EL environment. It can, theoretically, also include their productivity and performance indexes. It is possible, since CRIS architecture of the proposed research environment implies integration with research management system where data about research results can be correlated with data about research costs.

The scientometric portraits can be useful instrument of a research assessment.

Additionally to ordinary statistics about research players' productivity it allows a deep inspection of impacts in both aspects as a current state and as a dynamic process. A network of semantic linkages allows an assessment of a current distribution of usage characteristics, as well, impact's changes in time, for a single research result, a researcher represented by many research results, research projects and organizations.

Assessments on proposed scientometrics, if it is statistically significant, can answer: a) who used what research results as a basis for creating a new scientific knowledge (a "basement" type of usage that should have the highest positive assessment); b) whose research results prove/repeat or are proved by other results that can be assessed as an indicator of credibility; c) whose results are mentioned just as illustrations that should be assessed as a weak usage; d) whose results are criticized or disapproved that means assessment of suspicious research result with currently not clear impact.

Obtained in this way, assessments of research productivity and performance will be substantially more informative than the currently used citation indexes. Thus, using them in procedures of professional certification and in research funding schemas will create more effective incentives and motivations for scientists.

Item "d" of online scientometrics concept (see above) is fully implemented at Socionet and permanently works as Socionet Statistics section from 2007. Items "a" and "b" are implemented completely recently after running the service of linkages monitoring and now on this base we are designing a section of scientometrics portraits for researchers and organizations. Item "c" is partly implemented, since in June 2010 at Socionet DIS there are only few linkages with specified usage characteristics.

## **Conclusion**

We are designing a research EL environment called Socionet that makes possible a shifting of common research practice to the Open Science model. It based on the scientific objects-for-reuse concept that proposes a representation of some text fragments of research articles as an information object of research DIS designed to improve circulation and usage of research results. We propose a granularity of scientific articles to package research results as objects-for-reuse. To record the quality characteristics of research results usage we use a model of electronic citation with quality attributes. The attributes values that based on a proposed metrics are picked up to measure existed differences in research results usage. We utilize these ideas to develop an electronic depositing tool, which is integrated with DIS and allow scientists making semantic linkages between different information objects of DIS, including citation links

between articles and objects-for-reuse. We run automated monitoring service to trace all DIS changes. The service notifies scientists about important events (e.g. about establishing citation links with their articles, etc.) and build scientometric database. Accumulated scientometrics now include usage/impact quality characteristics, which can be used to improve research assessment.

One can expect that research community will get significant benefits from Open Science innovations, since it will produce: (a) better visibility of existed research objects-for-reuse; (b) better competition of research result to be used and cited; (c) clear picture on types of research results' usage and transparent usage statistics; (d) better efficiency of scientific circulations.

In Russia, the same as in many other countries, government and funding organizations would like to improve science regulations. But the efficiency of the new regulations is bottled up by some shortcomings of expert's panels and existed bibliometric on research performance (e.g. citation statistics).

In Russian Academy of Sciences (RAS) from 2010 is working a research information system "Results of Intellectual Activity" (RIA) aimed to serve 400 institutions of RAS with 30000 people in their staff. Main RIA RAS goals are to provide new research performance statistics and quality research evaluation to improve funding rules according new science regulators.

To remove some initial shortcomings and increases the RIA RAS efficiency we propose some kind of coexistence and data exchange between RIA RAS and Socionet. The main idea is to exclude human experts, where it's possible, from creating research performance statistics by: (a) giving researchers a method to register research results as computer readable scientific objects-for-reuse; (b) organizing a scientific circulation of it including methods for its using by research community in a computer readable form; (c) running automated monitoring services which forming/updating statistic of research producing/using. In this case the statistics for research assessment will be produced by the Science System, not by humans.

In this schema the RIA RAS will mandate researchers to register their objects-for-reuse at Socionet that pushes research results into better scientific circulation and produce quality usage statistics. The Socionet accumulates and processes quantitative and qualitative data about research performance, which will be integrated than into research assessment datasets of the first system and will be used into RIA RAS for evaluation of researchers and organizations.

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