Selection Methods of Digital Information Resources for Scientific Heritage Studies: A Case Study of Georgy F. Gause

Dmitry Prokudin
St. Petersburg State University,
ITMO University
Universitetskaya nab., 7/9
St. Petersburg, 199034, Russia
hogben.young@gmail.com

Georgy Levit
ITMO University
49 Kronverksky Pr.
St. Petersburg, 197101,
Russia
georgelevit@gmx.net

Uwe Hossfeld
Jena University
Am Steiger, 3,
07743 Jena,
Germany
uwe.hossfeld@uni-jena.de

ABSTRACT
Permanent growth of scientific information and the traditional dispersed form of its storing (books and journals) negatively affect its current use in the historical studies, for example, for estimating the role of certain scientists in the history of science. A possible way to overcome this challenge is the digitalization of scientific information. New digital databases appear worldwide. The growth of new informational technologies made these databases available for international scientific studies. Searching methods for already digitalized data need to be further enhanced and adapted to the needs of certain scientific disciplines.

Our objective is to explore the ways of using digital databases in the history of science and society. We suggest selection methods suitable for historical studies and determine their effectiveness on the example of the influence of a Russian biologist Georgy F. Gause (1910-1986) and his evolutionary concepts. We demonstrate how various combinations of search criteria meet certain needs of science historians. Finally, we provide general recommendations for searching and analyzing digital databases.

CCS Concepts
• **Information Systems→Digital Libraries and Archives** • **Information Systems→Information Extraction** • **Information Systems→Expert Search** • **Information Systems→Retrieval Efficiency** • **Applied Computing→Digital Libraries and Archives**

Keywords
Scientific Information; Digital Information Resources; Methods of Selecting Information Resources; Criteria of Selecting Information Resources; Digital Scientific Heritage; Georgy F. Gause.

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1. INTRODUCTION
Technological and scientific evolution of human society are determined by the permanent growth of the amount of information available. The explosive growth of information in the post-industrial societies is known as the “information revolution” or “information explosion” [10, 20].

The major mechanism behind the information explosion is the digitalization of information that accelerats the processes of its generation and storage by using communication technologies. The development of these technologies in the recent 15-20 years guaranteed global and instant access to digital information resources [2, 29, 36]. At the same time, it is important to emphasize that information technologies changed the research strategies as well. Scientific resources, on the one hand, stored in a traditional print form is digitalized, but on the other hand, new publications appear already as a digital product prior to hard copies. There are completely digital scientific venues as well (such as e-journals) [4, 5, 6, 9, 27, 30, 38].

However,these newest achievements generate new challenges. One of them is the dispersed character of potentially globally available scientific information. This results in difficulties for operating with scientific information since it is impossible to simultaneously access geographically and digitally separated storages (e-archives, e-libraries etc). The problem is well known for printed media since searching in paper catalogues is constrained by human abilities to operate with required information. even complete digitalization of traditional catalogues does not fully solve the problem of effective and quick search for certain information. For example, a book content is rarely explicated on catalogue cards, whereas papers are rarely given with key words and abstracts.

By contrast, digital scientific resources usually contain information on every single paper and abstract as well as metadata. In addition, such resources include powerful search engines. The majority of digital resources are connected to the internet and this makes them available for scholarly research [21, 23, 28, 32]. Besides, the digitalization of resources solves the problem of their long-term custody therefore contributing to the world’s cultural heritage preservation [1, 7, 13, 24, 25].

Current science is characterized by the intensification of both research processes and outreach of scientific information gained . Therefore, it is crucial for scientists to have an instant access to the growing amount of scientific information.

2. LITERATURE REVIEW

Historians use both traditional and digital archives. The latter have been established since 1990s. Large scale digitalization is taking place, which includes digitalization by authors themselves. [31]. This approach allows to work more efficiently with secondary sources.

The growth of the internet leads to better worldwide availability of digital archives and collections. This affects search strategies and modes of operating in the digital environment. Researchers develop new [12].

The growth of electronic scientific journals initiated the processes of establishing primary materials in a digital form. Moreover why their involvement into historical studies is not only a possibility, but a necessity in historical studies [34]. Recent observation demonstrates a permanent growth of impact of digital resources on historical studies [33].

Contemporary history of science employs various digital resources as well. Digital data is crucial for the so called "computational history of science". This new historical discipline uses big data– based approaches and computational analytical methods [22]. There are examples of using JSTOR for the purposes of science history by employing computational analytical methods [19].

The examples show that a comprehensive science historical study should be based on comparing various digital resources.

3. OBJECTIVES AND METHODS

Our objective is to explore the ways of using digital databases in the history of science and society. We provide two selection methods suitable for research on the history of science. Their efficiency is demonstrated on the example of the influence of Georgy Gause's concepts in the history of ecology and evolutionary theory.We demonstrate how various combinations of search criteria meet certain needs of science historians. Finally, we provide general recommendations for searching and analyzing digital databases for the purposes of historical studies to contribute to the preservation of scientific and cultural heritage.

We have selected the following criteria for the preliminary selection of digital resources (presented here in order of their decreasing significance):

- Inclusiveness in respect to the type of documents used. The major condition is the availability of abstracts of scientific papers. Therefore, we have excluded e-catalogues of libraries from the very beginning.
- An option to search metadata, for example, title, abstract, key words, publication years etc.
- An option of deep retrospective search back until the 1930s.
- A possibility to determine topics of publications.
- A possibility to search within all scientific fields

To verify the results of the search were used combined search query consisting of two terms connected by "and".We preferred services offering the search of the whole metadata and, if possible, full text publications.

4. CLASSIFICATION OF DIGITAL SCIENTIFIC RESOURCES TO BE USED FOR RESEARCH PURPOSES

Information technologies with an objective to accumulate and widely spread scientific knowledge are the most developed and offer convenient search mechanisms. They look like databases accumulating scientific publications metadata with a portion of full text search. They are, as a rule, available via the Internet [8]. These databases can be classified in various ways ad here we propose some of them.

First of all, one should separate information resources according to their type and determine the following categories.

1. *Electronic library catalogues*. These are the most voluminous databases storing printed editions of various kinds and together providing sources for the entire history recorded. Yet, by far not all library files are available in an e-form although the situation is getting better. There is one more problem as well. The Most important for scientists are papers in scholarly journals. However this is exactly the kind of publications that are not reflected in an e-catalogue of traditional libraries.

2. Digital repositories of scientific information. They became widely spread due to the occurrence of a new "open science" paradigm with the assistance of initiatives like Open Archives and Open Access. Digital repositories can be subdivided into the following categories:
1) *Institutional*, i.e. established by a certain scientific institution (university, research institutes, scientific centers etc.). This kind of repositories usually includes scientific publications and pre-prints of these institutions and are created by the way of self-archiving.
2) *Thematically* composed repositories established to accumulate outcomes of certain research directions [35]. They either are managed by certain institutions or offer an open access to all scientists.
3) *Repositories of scientific communities/societies* storing publications, which appear within the framework of these societies. Examples are e-archives of scientific conferences. Open repositories of this kind are fragmentary and presuppose no obligations of society members to publish their research in this very repository. Thus, single repository of that kind is usually insufficient for a complete bibliographical search, which is presuppose the use of such many repositories. The usage of many repositories at the same time is technically a problematic issue considering that repositories instantly renew their data.

3. The problem described above can be solved by using one more type of repositories: e-catalogues of open repositories. Currently, there are two best-known repositories of that kind: OpenDOAR (http://www.opendoar.org) and Registry of Open Access Repositories – ROAR (http://roar.eprints.org) which include the most complete information. OpenDOAR was founded in 2006 and is hosted by University of Nottingham, UK. At the moment OpenDOAR embraces 3300 entries. ROAR was founded in 2000 and is hosted by the School of Electronics and Computer Science at the University of Southampton, UK. It embraces 4400 entries. Both catalogues offer a possibility to establish new repositories and store files by institutions, societies and individual scientists. Besides, both catalogues offer a possibility to search content of the stored repositories.

4. The Fourth category is composed by digital e-journals and similar resources, which are, in fact, e-repositories. There are several programmatic platforms enabling publication of scientific journals. The major platform is the publicly available Open Journal System (OJS). It is an online publication system of the full cycle designed along the lines of the idea of electronic publishing house [3, 39]. Major publishing houses establish their own programmatic platforms and place there scientific periodic as, for example, SAGE. SAGE Journals Online (http://online.sagepub.com), Springer Link (http://link.springer.com), Taylor and Francis Online (http://www.taylorandfrancis.com) and so on. Such platforms allow to publish all necessary metadata, which can be indexed by indexing and search systems, for example, by Google Scholar as well as transferred to external information systems. For this pupose either an import of metadata in a certain format can be used or automatic transfer of metadata in accord with OAI-PMH. Metadata is be presented in the format Dublin Core, which is one of the wide spread standards [11, 37]. For example, these mechanisms are in use in the platform OJS. This is also the reason of its popularity. [OJS Stats. Public Knowledge Project. https://pkp.sfu.ca/ojs/ojs-usage/ojs-stats/]. As well as in the case of digital repositories, it is very difficult to track all newly appearing electronic scientific journals. To solve this problem was established the catalogue of electronic journals such as DOAJ, Directory of Open Access Journals (DOAJ, http://doaj.org), which was founded in 2002 jointly with the Lund University, Swedish National Library, and Royal Library in Stockholm. DOAJ embraces peer-reviewed electronic journals with open access. At the moment DOAJ offers more than 9000 journals and 2,4 million papers. Another service is the Directory of Open Access Scholarly Resources (ROAD, http://road.issn.org) founded by the International Center ISSN with the assistance of UNISEF in 2013. This catalogue embraces more than 18000 journals with open access and other open access publications.
5. There is one more type of electronic resources, so called, aggregators. Aggregators are information systems accumulating metadata of papers and other scientific texts registered in these aggregators. The major mechanism of increasing databases is the automatization of data exchange in accord with certain protocols, for example, already mentioned OAI-PMH. The description of any object available in the aggregator includes a reference to the source of the metadata. In case of open access resources a full text document can be downloaded. An example is the worldwide most powerful aggregator The OAIster® database (http://oaister.worldcat.org). It embraces more than 30 millions entries of more than 1,5 millions organizations-participants offering open-access publications [26]. This aggregator was designed by the Michigan University and will be currently operated by the Online Computer Library Center, Inc. (OCLC). OCLC is a public organization with an objective to widen access to the information and make information cheaper.
6. Indexing services offering metadata of periodicals should be mentioned here as well. Two biggest indexing services are Web of Science (Thomson Reuters) and Scopus (Elsevier). However the specifics of these kind databases make them not inclusive enough. Indexed journals should correspond to a number of quite strict criteria.
7. The last kind of resources is scientific social media like ResearchGate and Academia.edu, which became extremely popular in the recent time. Content of these media is created by individual scientists who upload full text papers and metadata or only metadata. Therefore, the information that is available on these media is fragmented.

All digital resources can be classified in accord with the availability of uploaded texts as well. There are open resources accessible without restrictions, commercial resources and indexing /abstracting services (WoS and Scopus) as well as mixed resources, i.e. only partly open.

An valuable aspect of digital scientific resources is the amount of available data. It can be only bibliographical entries, full metadata or even full text publications.

One can classify resoucrces in accord with the type of documents stored: monographs, periodicals, dissertations, edited volumes, conference proceedings, patents, reports, manuscripts, journal papers etc.

Another important characteristic is the scope of research directions presented. There are highly specialized resources like PubMed Central® offering a full-text archive of journal papers in the field of biomedicine, medicine, and biology. There are resources covering several scientific disciplines as, for example, ArXiv.org, which is free and covers math, informatics, astronomy, biology, statistics, and finances. There are polithematic resources without any thematic limitations such as The OAIster® database.

All characteristics mentioned above can be summarized in a table allowing to choose resources in accord with search objectives (Table 1).

Table 1. Important characteristics of digital scientific resources

Kind of Resource	Accessibility	Full text	Type of documents	Scientific fields
Library e-catalogue	free	no	All types except of papers	All fields
Repository	free	yes	All types	All fields/thematically constrained /highly specialized
Aggregator/ Catalogue	free	no	All types	All fields and topics
e-journal	free/ commercial	yes	articles	Highly specialized
Abstracting /indexig	commercial	no	articles	All topics
Scientfic social networkss	free	yes	All types	All topics

5. THE INFLUENCE OF GEORGY F. GAUSE AS A CASE STUDIES TO PROVE THE EFFICIENCY OF SEARCH IN VARIOUS DIGITAL RESOURCES

Georgii Frantsevich Gause (1910-1986) was one the most influential Soviet ecologists and evolutionary biologists [14, 15]. He is the first to coin the "law of competitive exclusion" claiming that two species competing for the same resource cannot coexist at constant population values [16]. His major book "The Struggle for existence" [16] published in Baltimore, USA, is claimed to be "one of the most influential writings in theoretical and experimental ecology" [18]. Remarkably Gause developed his concept while reading papers of his Western colleagues Vito Volterra (1860-1940), Alfred Lotka (1880-1949) and Raymond Pearl (1879-1940). Gause had also a letter exchange with all these authors.

Less known is that Gause made path-breaking developments in medicine and created a unique antibiotic Gramicidin S in 1942 [17]. Besides, Gause invested a great deal of his time investigating into the dissymmetry of protoplasm.

Gause incorporated several features making his suitable for our current case studies. He developed his concepts in a relatively isolated totalitarian state, but succeeded in publishing his major concept early in his career that made his name well known in the west. His ecological experiments are better known in the Western history of science as his antibiotics research and protoplasma studies. Gause escaped repressions during Stalin's time (although many of his friends and co-authors were arrested) and published continuously through his whole life. Therefore, measuring Gause's influence on international community is contributed to a general question on the impact of soviet science in various historical periods on the international scientific communities.

The objective of the current study was to estimate the influences of Gause on various branches of science using various search entries and repositories. We have compared Russian and Western resources relation to their efficiency, availability, and other quantifiable parameters. The present papers summarizes only preliminary results and should be seen as a case study. It does not offer an ultimate statement on Gause's influence abroad.

Empirical basis of the case studies.

In accord with the selected criteria and classification we have selected the following digital scientific resources:

- SCOPUS (http://scopus.com) covering all scietific fields and offering over 22,748 peer-reviewed journals, of which more than 4,470 are full open access.
  Besides, over 558 book serials are covered in Scopus, accounting for 34,000 individual book volumes and 1.3 million items More than 138,000 non-serial books (https://www.elsevier.com/solutions/scopus/content).
  The search question used was Gause AND competitive exclusion principle.
  Altogether 560 documents were found beginning with 1960. The results are filtered in accord with their field of research, document type, publication date. Citing publications were within the scope of search.
- Academic Search Complete (EBSCO, https://www.ebscohost.com/academic/academic-search-complete) is currently the most complete multidisciplinary database of scientific publications and includes full texts of more than 8500 journals of which 7300 are peer-reviewed. Despite of full text materials the database embraces abstracts and titles of more than 12500 journals as well as more than 13200 other publications including monographs, conference proceedings and so on.
  Publications are available in PDF format beginning with 1887 until now with a possibility to search through the full text. More than 1400 journals allow to search through the cited sources as well. The search entry used was "Gause AND competitive exclusion principle", 1934 – 2017. There were 248 documents found altogether. Representative results begin with the year 1969. Additional filters were used as well: years of publications, type of a source, scientific field.
- Web of Science Core Collection (http://webofknowledge.com) is a polythematic indexing and abstracting database founded by Thomson Reuters and embracing more than 13000 scientific journals worldwide. The search entry used was "Gause AND competitive exclusion principle", 1934 – 2017. There were 9 documents found. Representative results begin with the year 2005.
  Additional filters were used as well: scientific fields (as offers by WoS), type of a document, publication date.
- JSTOR (The Scholarly Journal Archive, http://jstor.org) is a digital archive embracing papers published in a 1000 best scholarly journals worldwide. It includes journals in social sciences and humanities as well as monographs and related materials. The search entry used was "Gause AND competitive exclusion principle", 1934 – 2017. There were 1722 documents found. Representative results begin with the year 1934. Additional filters were used as well: type of a document, field of research.
- OAIster (http://oaister.worldcat.org) is one of the biggest aggregators offering a possibility to search through the one million of open access publications as a part of «Open Archive Initiative» initiative. The majority of publications are stored in open access university repositories as well as in the open access journals, the number of which is instantly growing. The search entry used was "Gause AND competitive exclusion principle", 1934 – 2017. There were 6 documents found. Representative results begin with the year 2002. Additional filters were used: a type of a document, a publication date.
- PLOS (Public Library of Science, https://www.plos.org) is an e-resource founded in 2001 and including open access journals in medicine and biology.
  The search entry used was "Gause AND competitive exclusion principle".
  There were 68 documents found. Representative results begin with the year 2008.
  PLOS does not offer a mechanism of advanced search. There is no option to employ additional filters.
- Google Scholar (https://scholar.google.ru) is a full text database as well as an indexing system. Project was started in 2004 and covers all research fields and disciplines. The specificity of googlescholar is that it includes paper from leading journals as well as open access resources of other kinds such as unpublished dissertations and non-reviewed publications. The search entry used was Gause "competitive exclusion principle". 1770 documents of various kinds were found.
  GS does not offer advanced search mechanisms. Search results are given as a list without an option of further differentiation.
- PubMed Central (https://www.ncbi.nlm.nih.gov/pmc/) is partly full text open access archive in the fields of biomedicine and biology.
  The search entry used was: Gause "competitive exclusion principle".
  32 items were found. PubMed offers advanced search, for example, one can alternate the years of a publication in question.

- OpenDOAR (http://www.opendoar.org) is a repositories catalogue hosted by the University of Nottingham, UK. OpenDOAR has found 6 520 documents. This resource has no advanced search. The results are given as a list without any options.
- SpringerLink (http://link.springer.com) is a digital resource of publishing house Springer embracing more than 2700 scientific journals and more than 4000 publication series beginning with 1842 as well as 100000 books. The search entry used was: Gause competitive exclusion principle, 1934-2017. Alltogether 453 documents were found. Representative results begin with 1958. Additional filters were used: a type of a document, a field of studies.

After getting the results, we have proven the possibility to download lists of found documents. This option was not offered by all services. Generalized search results are summarized in a table below (Table 2).

Table 2. The results of searching for „Gause AND competitive exclusion principle“ within various digital information resources

Resource	Edvanced search	Number of results	Retrospective search from	Possibility to download results
SCOPUS	Yes	560	1969	Yes (CSV)
Academic Search Complete (EBSCO)	Yes	248	1969	No
Web of Science Core Collection	Yes	9	2005	Yes (CSV)
JSTOR	Yes	1 722	1934	Yes (RefWorks, EasyBib, RIS, Text file)
OAIster	Yes	5	2002	No
PLOS	No	18	2008	No
Google Scholar	No	1 770	-	No
PubMed Central	Yes	32	1972	Yes (XML text)
OpenDOAR	No	6 520	-	No
SpringerLink	Yes	455	1958	Yes (CSV)

6. CONCLUSIONS

Preliminary estimation of options offered by digital information resources allows choosing the most appropriate for certain research goals. Correspondingly, we have excluded from the analysis following resources:

- Academic Search Complete (EBSCO) found just a few documents and offered no possibility to download the results;
- Web of Science Core Collection – found just a few documents, offered no possibility to download the results;
- OAIster – found just a few documents and offered no possibility to download the results;
- PubMed Central – found just a few documents;
- PLOS – found only a few documents and offered no extended search, additional filters and results lists downloads.
- PubMed Central – found only a few documents and offered no extended search and additional filters.
- GoogleScholar and OpenDOAR were best in respect to number of found results; however, they cannot be used for further research as well because these resources do not offer no extended search, no additional filters, and no possibility to download the results.

The most suitable resources for our objectives are JSTOR, SCOPUS and SpringerLink. Apart from quite representative search results these platforms offer convenient download instruments to be used in further mathematical analysis.

Further research of the topic is to include a mathematical and a historical analysis of gained results. First of all, it is necessary to compare the outcomes of downloads to exclude double referencing to the same documents.

Besides, we are going to use in our search Russian and Russian-language scientific digital resources, because Georgy Gause was a Soviet scientist publishing abroad.

The evaluation of Russian digital resources potential is important for preserving Russian scientific heritage and enabling broad public and scientific use of them.

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