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DIGITAL REPOSITORIES AND THE FUTURE OF PRESERVATION AND USE OF SCIENTIFIC KNOWLEDGE

DIGITALNI REPOZITORIJI I BUDUĆNOST OČUVANJA I PRIMJENE ZNANSTVENOG ZNANJA

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Abstract
Information and communication technology has a great influence on scientific communication and work of scientists. Ways in which research is conducted have changed; science has become more highly collaborative; network-based, and data-intensive. The existing system of scientific publishing is experiencing pressure for change under the influence of the exponential growth of information production, the dramatic increase in subscription fees, the increasing storage cost of printed documents, and the increasing power and availability of digital technology. To conduct their research more effectively scientists need modern resources of digital information which would support their endeavor. Digital repository is one such type of information resources. Digital repository is an institutional digital archive of the intellectual product created by the faculty, research staff, and students of an institution and accessible to end users both within and outside of the institution. Digital repositories carry a great potential for the advancement of scientific research. Digital repositories can store different file formats and types of content. An institutional digital repository can contain e-prints of scientific papers, research data, but also e-learning materials and other forms of institutional intellectual outputs. As the number of open access digital repositories grows, it has become evident that institutional repositories are now clearly and broadly being recognized as essential infrastructure for scholarship in the digital world.

Sažetak
Informacijska i komunikacijska tehnologija ima velik utjecaj na znanstveno komuniciranje i rad znanstvenika. Načini provođenja istraživanja se mijenjaju; znanstvenici sve više surađuju; računalne mreže sve se više koriste uz nastanak i korištenje sve veće količine podataka. Postoje sustav znanstvenog objavljivanja nalazi se pod pritiskom promjena zbog eksponencijalnog rasta informacijske produkcije, dramatičnog povećanja cijena pretplata (na časopise), povećanih troškova pohrane tiskanih dokumenata i rastućom snagom i dostupnosti digitalne tehnologije. Za učinkovitije provođenje znanstvenih istraživanja, znanstvenicima su potrebni suvremeni izvori digitalnih informacija koji su pružiti podršku njihovim aktivnostima. Jedna takva vrsta informacijskih izvora su i digitalni repozitoriji. Riječ je obično o institucijskim digitalnim arhivima intelektualnih rezultata rada koje su stvorili nastavnici, znanstvenici i studenti neke institucije i koji su dostupni krajnjim korisnicima u instituciji i izvan nje. Digitalni repozitoriji imaju velik potencijal za napredak znanstvenih istraživanja. U digitalnim repozitorijima moguće je pohraniti razne formate datoteka i vrste sadržaja. Institucijski repozitorij može sadržavati e-print verzije znanstvenih radova, podatke istraživanja, ali i obrazovni materijal i druge oblike institucijskih rezultata intelektualnog rada. Kako broj digitalnih repozitorija sa slobodnim pristupom raste, postalo je očito da su institucijskih repozitoriji postali priznati kao esencijalni dijelovi infrastrukture znanosti u digitalnom svijetu.

1. INTRODUCTION

As information and communication technology is changing almost every aspect of our lives, it has become clear that scientific communication is also being restructured for the digital environment /**1**/. The traditional system of scientific publishing is now over 300 years old and it has become apparent that some parts of that system require change to meet information needs of modern scientists. The existing system of scientific publishing is experiencing pressure for change under the influence of the exponential growth of information production, the dramatic increase in subscription fees, the increasing storage cost of printed documents, and the increasing power and availability of digital technology /**2**/. As a consequence of widespread proliferation of computers, networks, and networked information

today, access to information has become relatively easy, inexpensive, widespread, and democratic /**3**/. These and other developments in scientific information infrastructure have lead to changes in conducting research. According to Van Sompel et al. improvements in computing and network technologies, digital data capture techniques, and powerful data mining techniques enable research practices that are highly collaborative, network-based, and data-intensive /**4**/. The biggest problem of the global digital environment today is the abundance of information and their organization. The volume of scientific literature typically far exceeds the ability of scientists to identify and utilize all relevant information in their research /**5**/. The current and prospective era of information abundance will challenge many basic assumptions and practices about safeguarding, protecting, filtering, preserving, evaluating, purging, describing, cataloguing, and vetting information for the purposes of teaching, learning, and scholarship /**6**/. The widespread availability of digital content is creating opportunities for new forms of research and scholarship that are qualitatively different from the traditional way of using academic publications and research data /**7**/. In Europe this is called e-science and in USA cyberscholarship. In addition to the problem of abundance of digital information, another problem has arisen. According to Honey, we can no longer rely on the physical print copies of the journals to be stored in perpetuity because classic journal subscription no longer ensures availability of published scientific knowledge to future scientists /**8**/. Stumm emphasizes that the publishers (as important stakeholders in this example) are commercial enterprises that do not plan for their own demise and should the publishing firm shut its doors for any reason, the information that libraries rely on may disappear /**9**/. This leaves the institutions (such as libraries) that were preserving the content of our scientific heritage in a printed format incapable of continuing with the same activity /**10**/. To avoid the interruption of access to important material almost all libraries have implemented some aspect of digital media into their collections /**11**/. They are now facing different kinds of problems such as capturing, managing, distributing, and preserving the digital material that is produced. Effectively dealing with this content requires new technological infrastructure, new policies and procedures, new core competencies of staff, and new business lines and cost models which leads to significant transformation of the current models of institutional scientific content management /**12**/. As a result, scientific community as well as publishers and librarians are investigating new forms of organizing scientific knowledge. One such form is institutional digital repository. Institutional digital repositories provide an institution with a mechanism to showcase its scientific output, centralize and introduce efficiencies to the stewardship of digital documents of value, and respond proactively to the escalating crisis in scientific communication /**13**/. This article will put focus on several important issues related to digital repositories and the development of these new information systems for exchange of scientific information.

2. TOWARDS UBIQUITUS DIGITAL SCIENTIFIC ENVIRONMENT

As early as 1990, Harnad observed some of the major changes in scientific communication. He wrote that the whole process of scientific communication was undergoing a revolution comparable to the one occasioned by the invention of printing. At that time, focus of his analysis were pre-print works discussed informally with colleagues, presented more formally in seminars, conferences and symposia, and distributed still more widely in the form of preprints and tech reports that have undergone various degrees of peer review. His final point was that it has now (at the end of the 20th century) become possible to do all of this in a remarkable new way that is not only incomparably more thorough and systematic in its distribution, potentially global in scale, and almost instantaneous in speed, but so unprecedentedly interactive that it will substantially restructure the pursuit of knowledge /**14**/. The distribution of scientific works on the global scale described by Harnad in 1990 is possible today with the help of digital repositories. Lynch offers his viewpoint regarding the current changes in science which became more data oriented. For him, the revolution in scientific communications is not limited to the development of new genres of scientific works that are enabled by the digital medium; even traditional forms such as journal articles now frequently include supplementary datasets and analysis tools. In addition, Lynch points out that scholarship has become data intensive; it is supported and documented by data and tools that complement interpretive works of authorship. Finally, he concludes that only an institutionally based approach to managing these data resources can provide a comprehensive dissemination and preservation mechanism for the data that supports the new scholarship for the digital world /**15**/. Institutional support to work of scientists will play a crucial role in near future in universities want to be leaders in scientific endeavor.

3. DIGITAL REPOSITORIES

Digital institutional repository (a digital information repository that is a part of university or other institution) is a digital archive of the intellectual product created by the faculty, research staff, and students of an institution and accessible to end users both within and outside of the institution, with few if any barriers to access /**16**/. For Branin, digital repositories are systems and service models designed to collect, organize, store, share, and preserve an institution's digital information or knowledge assets worthy of such investment. A digital repository in fact can be owned and managed by an individual, a small group, an institution or commercial organization, a consortium of organizations, or a government entity /**17**/. For Lynch, a university-based institutional repository is a set of services that a university offers to the members of its community for the management and dissemination of digital materials created by the institution and its community members. It is most essentially an organizational commitment to the stewardship of these digital materials, including long-term preservation where appropriate, as well as organization and access or distribution /**18**/. For McLean and Lynch institutional repositories are archival, stewardship and dissemination systems for content that have a fairly heavy policy component in terms of who can deposit, what metadata is required for deposit, acceptable formats and the implications of format choices for institutional preservation guarantees /**19**/.

Digital repositories can be divided into at least two categories: those that serve universities, or several university campuses (they are called institutional repositories). Institutional repositories organize themselves along organizational or political jurisdictional lines, and they collect and manage digital assets in a variety of formats and subjects for the constituents within that jurisdiction /**20**/. Another type of digital repositories is one that serves a scientific discipline, or several closely related disciplines (it is called disciplinary repository) /**21**/. Disciplinary repositories focus on the collection of digital assets in a subject area /**22**/. Focus of this article is on institutional digital repositories. Digital repositories are related to digital libraries, since digital libraries consist of digital collections which are similar to digital repositories. Digital libraries offer a wide range of new access opportunities that are absent in the traditional environment, including remote access, 24-hour access, and multiple users for single sources /**23**/. For Farooq et. al. digital libraries are repositories for information search and retrieval, but they are also collective resources that attract people and help to form scientific communities where users are building social networks, sharing knowledge, and more /**24**/. Students and scientists can benefit from digital libraries. As Downs and Friedman suggested, digital libraries containing representations of original works provide opportunities for students and scientists to conduct research from personal computers and workstations located in their homes, offices and laboratories /**25**/.

4. CONTENT OF DIGITAL REPOSITORIES

Digital repositories can store different file formats and types of content. An institutional digital repository can contain e-prints of scientific papers, research data, but also e-learning materials and other forms of institutional intellectual outputs, which are generally not published or preserved elsewhere /**26**/. Van Westrienen, and Lynch distinguish several types of material commonplace in repositories they investigated: articles, books and theses, primary data, video, music and the like, course material and other types of material /**27**/. Jones offers his view of the matter by starting his list of material with archived research paper with the pre-print, the post-print, the PDF and the TeX versions all connected together such that you always know which version you are looking at and where you can look for others and continues with heterogeneous network of units of scientific work which range from journal articles, through learning objects, and on to specific sub-sections of continuous data /**28**/. As it is evident from these examples, digital repositories are not limited to a single file format or a content type. Instead they can and do include new and emerging content types and file formats, as well as cutting edge technology capable of transfer of information over great distances within a fraction of time. Diversity of content in digital repositories suggests various possibilities of its inclusion in teaching process at universities. In that sense, universities have an important role in the current information and knowledge society: as producers, transmitters, and disseminators of scientific knowledge and professional know-how, which makes them vital in the development of twenty-first century citizens. These diverse content, or, as Waters calls it digital assets, represent resources for research and teaching, which will play an important role in higher education for training students' research methods. They should be managed to advance knowledge and improve education. As scientists in different scientific fields gain experience with and develop discipline-based methodologies for using large-scale digitized content, as well special

collection and new media collections, they will need to incorporate the material and train students in the research methods /**29**/.

5. DIGITAL REPOSITORIES AND CHANGE OF COMMUNICATION PARADIGM

Scientists and librarians are looking for a replacement or at least an enhancement for scientific journals, information resources that have been defining scientific communication for centuries, and / or delivery of the content published in journals to the place of scientists' work. As the number of digital repositories available on the internet grows, scientific community investigates their good and bad sides in order to estimate whether digital repositories are possible and appropriate replacement for printed journals. To find out whether digital repositories can inherit the practice of printed journal, Prosser compared functions of traditional printed journals and digital repositories. First, he singled out traditional functions of journals /**30**/:

- Registration - the author wishes to ensure that she is acknowledged as the person who carried out a specific piece of research and made a specific discovery;
- Certification - through the process of peer-review it is determined that the author's claims are reasonable;
- Awareness - the research is communicated to the author's peer group;
- Archiving - the research is retained for posterity.

Then he compared journals with digital repositories which showed that digital repositories mirror at least three functions of traditional journals:

- Registration – by depositing in the repository the researcher would make claim to their discovery;
- Awareness – by constructing the repository to OAI standards the institution would ensure that the researcher's work would be found by search engines and available to their peers. New alerting services could be developed that would inform readers of new papers deposited in any repository that matched their research interests (in the same way that journal table of contents can be received);
- Archiving – the institution would be responsible for maintaining the long term archive of all the work produced by members of that institution. This would place the focus of archiving back onto the library community where it has rested for centuries, rather than on the publisher community where it has migrated following the transfer from print to online. In many cases the research library will be best placed to maintain over many decades an archive of its own research.

In addition to the enumerated three functions of the traditional journal, Prosser suggested that there are many benefits to institutional digital repositories /**31**/:

- For the individual:
  - o They provide a central archive of the researcher's work;
  - o By being free and open they increase the dissemination and impact of the individual's research;
  - o They act as a full CV for the researcher

- For the institution:
  - o They increases the institution's visibility and prestige by bringing together the full range and extent of that institution's research interests;
  - o They act as an advertisement for the institution to funding sources, potential new researchers and students, etc.
- For society:
  - o They provide access to the world's research;
  - o They ensure long-term preservation of institutes' academic output;
  - o They can accommodate increased volume of research output (no page limits, can accept large data-sets, 'null-results', etc.).

Other authors enumerated pros and cons for institutional digital repositories too. Yakel pointed out how institutions have incentives to preserve their own digital assets since they have created them. The down side of institutional repositories is that within institutions there may be an opposition to the creation of digital repositories, which can lead to situations where the quality of digital objects may vary and the originating archives or special collections may not have adequately created digital objects (e.g. assigning appropriate metadata, migrating objects regularly), creating extraordinary problems for the institutional repository if it wants to preserve these objects /**32**/. Conway wrote about the critics of the institutional repositories movement who stated that the technologies and associated policy frameworks are too limited, too narrowly construed, too political /**33**/. Davis and Connolly investigated use of institutional repository at Cornell University and concluded that it was largely underpopulated and underused by its faculty /**34**/. These examples demonstrate existence of number of unresolved issues related to digital repositories and their position at universities which is still uncertain in some cases. Another important author, Crow, suggested that institutional digital repositories provide a response to two strategic

issues facing academic institutions: 1.) they provide a critical component in reforming the system of scientific communication—a component that expands access to research, reasserts control over scholarship by the academy, increases competition and reduces the monopoly power of journals, and brings economic relief and heightened relevance to the institutions and libraries that support them; and 2.) they have the potential to serve as tangible indicators of a university's quality and to demonstrate the scientific, societal, and economic relevance of its research activities, thus increasing the institution's visibility, status, and public value /**35**/. Universities should make an additional effort to realize the potential of digital repositories (those which don't have any digital repository active) and to enhance their research capacities in order to facilitate new scientific discoveries. We should bare in mind that the publishing industry is still very strong and that it also uses Internet heavily for aggregation and delivery of scientific information on a commercial basis. Therefore, it is not realistic to expect that the publishing industry will abandon the current model of publishing they own and support. However, scientific community can put a pressure on publishers to slowly change their current practice and find a new organizational and financial model that would satisfy both publishers and scientists and make sure that digital repositories at universities (where most scientific articles are written) will have certain future as places of preservation of scientific knowledge.

6 DIGITAL REPOSITORIES AND PRESERVATION OF SCIENTIFIC KNOWLEDGE

Digital repositories have another important role – long term preservation. As Hockx-Yu suggested, the ease with which digital information can be created, combined with the huge increase in computer power and network bandwidth, has led to the proliferation of a vast amount of 'born-digital' data, especially in science and engineering, where petabytes (10 ^ 15 bytes) of data are being generated by scientific instruments on a daily basis. Digital repositories should secure long term preservation and curation so as to ensure that data generated today can survive the changes of technology and can be accessed in the future /**36**/. Preservation is not only related to data produced by scientific research but it is also related to old (i.e. existing) and new journal articles, which are still the most important media in scientific publishing. As King and Tenopir pointed out, scientific journals are read over a long period of time, and older articles may not be available electronically. When journals become available electronically, they are rarely made available retrospectively. The danger is that, in the future, older articles will be ignored because they are not available electronically /**37**/. Pinfield and James confirmed the existence of the same problem of loosing digital information. In their article about preservation of e-prints they drew attention to a problem of loosing digital content in open access repositories. They claimed that it would be an irony if a paper in an open-access e-print repository could be accessed today and yet in ten years' time had been allowed to decay so that it would be inaccessible. Preservation is necessary to protect open access to the content /**38**/. Digital institutional repositories can, it this case, serve as sources of older issues of most important scientific journals. This can be achieved by following preservation principles that Conway suggested and which can be directly applied to institutional digital repositories: longevity, choice, quality, integrity and access /**39**/. Another author, Wheatley, presented requirements for the long term accessibility of archived objects in a digital repository. He broke down the process of preservation to 4 key functional goals /**40**/:

1. Data can be maintained in the repository without being damaged, lost or maliciously altered;
2. Data can be found, extracted from the archive and served to a user;
3. Data can be interpreted and understood by the user;
4. Goals 1, 2 and 3 can be achieved in the long term.

Generally speaking, listed approaches to the key issues regarding the role of digital repositories illustrate that this type of online information resource has already become an important part of the modern scientific communication. Another important and closely related reason for the growing popularity of digital repositories in resolving the problem of long term preservation is the cessation of building of library collections. Steenbakkers stated that until recently, libraries bought printed journals and stored them in libraries where users could easily access them. As publishers offered digital versions of the same journals, libraries started to license journals (i.e. access to journals on the internet) and stopped buying printed copies. Libraries stopped compiling collections and digital versions of journals remained with the publisher. As a consequence, the permanent availability of the information that implicitly used to be offered by library collections is no longer guaranteed to the user /**41**/. It is a perfect opportunity for

digital repositories to step in and offer long term preservation of licensed journal content in addition to open access material they already store. Andrews proposed two major benefits for providing journals online. The online content becomes fully searchable, allowing a researcher to identify every occurrence of a particular word, phrase, or name in every issue of a journal. Additionally, older journal issues may not be held by many institutions, and over time those which are held may be at risk of accidental damage or loss /**42**/. In case of digitization and storing in digital repositories, they would remain accessible. There also some down sides. Digitized journals lack additional material beyond the articles themselves: example, covers, introductory notes, editorial boards, and advertisements. Without such material, the journal is not technically complete and this material should be digitized as well /**43**/. Nevertheless, digital versions of constantly increasing number of journals are used more frequently every day, as they are accessible in open access digital repositories where they can be used without paying fees or licenses (e.g. E-print in Library and Information Science at http://eprints.rclis.org/ or Hrčak at http://hrcak.srce.hr/).

7. CONCLUSION

Although many scientists are unsatisfied with the current system of scientific publishing and would like to see a new system in place, the complexity of the current system suggests that this change won't happen quickly and won't be easy to implement. Consequently, the institutional repositories should be recognized as a complement and a supplement, rather than a substitute, for traditional scientific publication venues /**44**/. During the time of transition, we must investigate all good and bad sides of digital repositories and open access in order to make the right decision regarding publishing of scientific knowledge and its preservation. This is especially important if we want more open access institutional digital repositories to be available without constraints and fear of loosing important scientific discoveries as well as loosing already published scientific knowledge that is still owned by major publishing houses if they ever decide, for some currently unpredictable reason, not to support digitization of older scientific books and journals. Free online availability of scientific literature offers substantial benefits to science and society. To maximize impact, minimize redundancy and speed scientific progress, authors and publishers should aim to make research easy to access /**45**/. Open access digital repositories can make this idea come true. As the number of open access digital repositories grows, it has become evident that institutional repositories are now clearly and broadly being recognized as essential infrastructure for scholarship in the digital world /**46**/. With rapidly changing technologies, users now desire and expect transportable content that can be utilized within various digital environments and reused in multiple formats, and they need forums for the rapid exchange of ideas with both on-campus and external communities /**47**/.Van Westrienen, and Lynch concluded that it will be very important to gain a better ongoing understanding of the extent to which institutional repositories are necessary to support developments related to e-science and e-research, or indeed for a wide variety of other purposes beyond managing and providing access to relatively traditional faculty publications, and how actively they are being used for these purposes /**48**/.

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