SUPPORTING SCIENTIFIC INCLUSION: NOVEL APPROACHES FOR THE REPRESENTATION AND ASSESSMENT OF SCIENTIFIC KNOWLEDGE OBJECTS

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Supporting Scientific Inclusion: Novel Approaches for the Representation and Assessment of Scientific Knowledge Objects

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Abstract. Developing countries face several challenges while trying to keep up and contribute to global scientific and technological advances. These problems persist despite the emergence of several new web-based communication opportunities that could potentially be used to bridge this knowledge gap. This paper introduces a conceptual and infrastructural platform (named LiquidPub platform) to address these problems and opportunities. We specially focus on the representation of content as Scientific Knowledge Objects (SKOs) and on a Resource Evaluation system (ResEval) for assessing the value of research, while also exploring the potential impact that the proposed concepts, methodologies and tools offer for both developing countries and the scientific community at large.

Keywords: Developing countries, Scientific research, Knowledge representation, Document evolution, Scientific artifacts, H-index, Impact assessment.

1 Introduction

A great majority of Latin American countries are within the groups called "Scientifically Lagged Countries" and "Scientifically Developing Countries" by the World Bank [1]. According to this study, countries from these two groups are below the average in science and technology production. On the other hand; United States, Japan, and several European countries are from the "Scientifically Advanced Countries" group, which continue to account for around 90% of all research and development spending in the world. The previous fact represents also a more general concern for the governments of these countries lagging in science and technology, due to the fact that investment in research and technology is often attributed to help drive

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the economic growth and development of the country (e.g. Japan, India, South Korea).

Even if the science and technology are not being produced internally, it is normally in the best interest of both higher-level education institutions and companies to have access to these advances to keep themselves as updated as possible. This is especially true in highly-dynamic environments like the ones related to informatics.

Fortunately, the rapid growth of Internet has aided the communication and access to an enormous breadth of scientific and technological materials, and also bridged the physical distances existing between distant researchers. But even with the help of the network of networks, there are some challenges related to how knowledge, science and technology are handled [2]:

- *Access*: despite the efforts of initiatives like PLoS[2] and Open Access (OAI)[3], publishers are still working as "renters of access" [3] for most of the formal scientific content available on the Internet. This is specially limiting for the small institutions with small budgets that are common in developing countries.
- *Search and evaluation:* the massive amount and variety of information now available through the Internet may also represent a problem for resource/time-capped readers. Known as the information overload [4], this problem makes imperative to be able to search and evaluate information at once in order to display first the results that are more relevant to the reader's needs.
- *Contribution and collaboration:* the current formal scientific publication systems do not favor the amounts of reuse and collaboration that would enable emerging research groups to contribute to global science.
- *Discussion and consulting*: participating in scientific conferences is currently one of the main methods used for discussing, making questions and networking (i.e meeting potential research collaborators or mentors). Nevertheless, budget-limited research groups have difficulties with the costs involved in attending to these conferences.

This paper first introduces (in Section 0) the main concepts and infrastructure explored within the LiquidPub (Liquid Publications) project[4], introduced in [5]. We then focus our attention to two of the components of the LiquidPub platform, namely the Scientific Knowledge Object (SKO) representation model for scientific resources (Section 0) and the ResEval Assessment tool (Section 4). Finally, throughout the whole paper but more specifically in the final Section 0, we explore the potential impact and advantages of the proposed concepts, methodologies and tools both for developing countries and the scientific community at large.

2 LiquidPub Framework

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[2] http://www.publiclibraryofscience.org

[3] http://www.openarchives.org

[4] http://project.liquidpub.org/

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LiquidPub is a Future and Emerging Technologies (FET) project that proposes a paradigm shift in the way scientific knowledge is created, disseminated and evaluated.
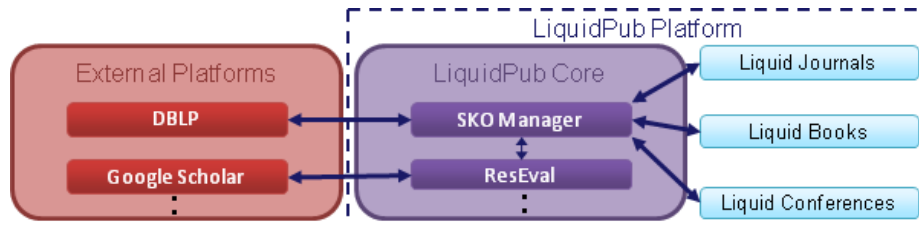

Figure. 1. LiquidPub simplified architecture.

Figure. 1 shows a simplified architecture of the LiquidPub platform. Briefly, at the core of the platform there are two main modules:

- a new model for the representation of scientific resources (the Scientific Knowledge Object Manager) that supports collaboration, versioning, evolution and credit attribution of the individual contributions to a line of research.
- a module to evaluate the social and societal impact of a given scientific contribution and supporting the SKO manager in the complex and delicate credit attribution process.

Data sources for the platform are potentially all scientific digital artifacts present on the web, but in particular web sites and services specialized on scholarly content like Google Scholar and DBLP (as example of freely available services), but also Web of Science, SpringerLink, IEEE Xplore, ACM Digital Library, ScienceDirect or Scopus (as example of commercially available services).

At present, the LiquidPub platform is being developed on the basis of the user requirements coming from three specific use-cases for the LiquidPub project, namely Liquid Journals, Liquid Books and Liquid Conferences. The following subsections will briefly introduce the LiquidPub use-cases and their potential impact to the discussed set of problems of developing countries. Then in the subsequent sections, we will detail the two main modules of the platform: SKO manager module and ResEval module.

2.1 Liquid Books

In most of the developing countries conducting research, developing technological advances or even organizing teaching material is considered almost a luxury [6]. Because of this, it is not infrequent for researchers and teachers to hold several other jobs to "finance" their research or to try to collaborate between each other or with more developed countries.

As a possible answer to the previous, Liquid Books[5] is a work-in-progress concept from the LiquidPub project development team whose objective is to facilitate the

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[5] http://project.liquidpub.org/research-areas/liquid-book

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creation of new knowledge and knowledge artifacts. To accomplish this, through a strong focus on version control and branching, Liquid Books keep track and mediate collaboration between a medium/big number of participants while also encouraging reuse of already existing content. Some similar initiatives include DynamicBooks[6], which focuses on the classroom uses; and Wikibooks[7] and the OpenBook project[8] that are more concerned on the creation of artifacts by using wiki-like creation environments.

In a concrete example of a Liquid Book that is currently being tested in one of the courses at the University of Trento, all the materials (e.g. slides, exercises, exams, references) produced by a group of professors from different countries that are needed for the teaching of a course about mathematical logic are kept in an SVN[9] repository that tracks every change and added material. The teachers are then able to select and order the material from the repository (normally slides) into the presentation that they would use for the course's lectures and for disseminating this content to his students. But the evolution of the course's content does not end there; students are encouraged to submit corrections, their note classes, exercises or related works for each of the lectures. After a short review by the course's teachers, these materials are incorporated into the course's repository. Future plans for this content includes using it for next instances of the same course (in the following years or at other universities/countries) and eventually releasing a conventional "solid" book from the content in the repository.

There are still various (mostly copyright and licensing) issues to solve before the Liquid Book model of collaboration can be widely applied but, regardless of this, it shows an interest promise of empowering collaboration and reuse in the creation of scientific and technological content. Both of which could potentially help authors from developing countries to contribute and obtain credit in a more global scale.

2.2 Liquid Conferences

While finding and creating knowledge are essential parts of the research process, for knowledge to be truly useful, it should be shared and discussed with other researchers or users/stakeholders. It is for this fact that outgoing and incoming communication with other researchers is also a very important aspect of research and one in which scientists in developing countries are normally handicapped in [7]. This is mainly because, despite the existence of several other communication methods, the discussion and broadcast of most findings are still done face to face and through the old conference model.

Liquid Conferences[10] are a work-in-progress concept created by the LiquidPub project development team. It is based around providing a virtual environment that

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[6] http://dynamicbooks.com/

[7] http://en.wikibooks.org/wiki/Main_Page

[8] http://openbookproject.net/thinkcs/

[9] http://subversion.apache.org/

[10] http://project.liquidpub.org/research-areas/liquid-conferences

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would allow the broadcast and discussion of science (without the related costs involved in traveling to conventional conferences).

An upcoming example, developed to comply with the main concepts of Liquid Conferences, is the Interdisciplines[11] website. Developed by CNRS from Paris, the Interdisciplines site allows creating web conferences that define their own panelist, moderators and accepts submissions from authors. Once accepted, each paper is open for discussion for a short period (emulating the discussion that happens at real conferences) and then each of these papers is archived with its discussion [8]

2.3 Liquid Journals Use-case

The Internet has given us access to scientifically relevant blogs, unprocessed datasets, and news articles among others. These "alternate" informal resources may not be as certified or recognized as formal scientific papers but they i) are more easily accessible (journals and papers can sometimes only be accessed behind pay walls) and ii) undeniably contain scientific and technological knowledge that some may find useful. For these reasons, it is now increasingly more important for the people that want to have access to the latest science and technology of a particular area (especially for those with limited resources) to know where and how to "cast their nets in the seas of knowledge" [9].

Liquid Journals[12] are used to help the research-interested people to focus their limited attention spans on a tailored information resource that it is automatically adapted and updated, according to the researchers' definition of "interestingness" and "relevance" [10].

Consider, for example, a high-school level informatics teacher that wants to keep his classes updated to the latest developments in the area of web services. Normally, he would need to visit expensive (probably unavailable in most developing countries) libraries or to navigate an enormous amount of papers, articles, blogs, among others that may (or may not) contain the information he is interest in. The use of Liquid Journals would help this teacher by enabling him to create and configure his own journal that would aggregate, automatically update and order all this freely available content according to the teacher's specifications. The same can also be applied to medical professionals that want to keep themselves updated with the latest discoveries and clinical trials related to their specialization, the owners of a small/medium enterprises and dedicated farmers wanting to keep up with innovative production methods.

Liquid Journals (just like the regular "solid" journals) are also platforms for dissemination, collaboration and discussion of ideas. Going back to the informatics teacher example, once his Liquid Journal is configured and running, he may decide to share it with his students so they could also follow and add to this evolving resource or he could decide to publish it more widely so it can be used by other teachers as a reference point for their own classes.

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[11] http://www.interdisciplines.org/
[12] http://project.liquidpub.org/research-areas/liquid-journal

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Finally, it is also important to remark the importance of Liquid Journals to increase the visibility of research, as it is often the case that the research and advances conducted in developing countries have a harder time getting published and noticed [7]. Liquid Journals, on the other hand, basically equate publishing to posting content on the Web; while also helping other people find this content according to its nature and quality, rather than on its provenance.

3 The SKO Model

SKO stands for Scientific Knowledge Object that, as shown in Figure. 1, stands at core of the LiquidPub platform. SKOs allow a variable granularity and multi-faceted representation of today's scientific resources and can be used to capture their evolution/maturity in time and compute credit attribution. In particular the information captured in the SKO may be used to support both standard metrics like citations and new social-based metrics emerging from the use of Web2.0 technologies.

A very early version of the SKO model is described in [11]. In this section we introduce a new and improved version of this work.

3.1 Structural Dimension

The SKO structural dimension is based on a multi-layered approach mainly aimed at enabling and facilitating the composition, reuse and collaborative creation of scientific resources. Furthermore, it provides the base for related works on improving the evolution, credit attribution, and search/navigation of these artifacts.
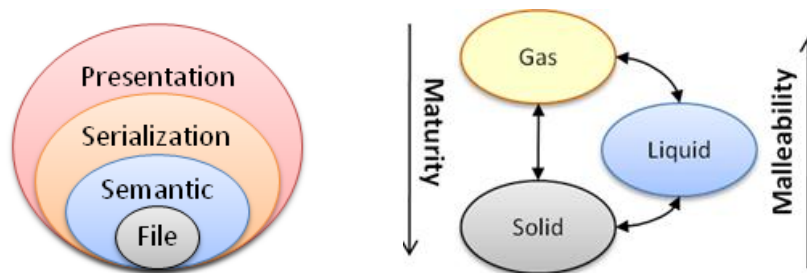

Figure. 2. Structural layers of the SKO model and Evolution states of the SKO model

The four layers introduced in the left side of Figure. 2 are:

- *File Layer*: foundational layer and main connection to well-established and commonly-used content and standards. This layer contains the actual content or data from the scientific resource.
- *Semantic Layer*: the semantic layer adds attributes and relations to the content from the file layer, which are used to specify the context and concepts to which they

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refer and ultimately arrange all the content from a scientific resource into a graph-like structure. Examples of this layer include the metadata-based components from documents like the abstract, keywords and even their introductions; along with relations like citations, composition or other semantic relations.

- *Serialization Layer*: selects and organizes the content and the semantic metadata from the previous layers into a linear sequence of information, which is easier to understand by human consumers. By varying the information in this layer it would be possible to create different artifacts (e.g. documents, slides, or blogs) from the same basic knowledge repository (i.e. semantic and file layer objects); these are called different *executions* of the same SKO. For example, by creating objects in this layer it would be easy to generate automatically sections like the Table of Contents and Bibliography or even more abridged versions of the same document (as the only thing that really changes between all these is the selection and organization of data from a common source).

- *Presentation Layer*: enables the rendering of the previous layer's output into several presentation styles (e.g. colors, font types, columns, etc) and formats (e.g. pdf, doc, etc.). By varying the information in this layer it would be possible to create different styles of the same artifact (e.g. single column, double column, text to speech, etc.); these are called different *presentations* of the same SKO and they must contain always the same exact data and knowledge (albeit presented in a different style).

3.2 State-based Evolution model

The State-based evolution is introduced to abstract away complicated properties from scientific artifacts (e.g. certification, persistence). Through an easy-to-understand metaphor based on the most commonly known states of matter, this evolution model introduces three discrete states for scientific artifacts. The right side of Figure. 2 introduces the Gas, Liquid and Solid states. Much like the physical states of matter, the same object/resource may have very different properties according to the state that it is in.

Table 1. Main properties of the three evolution states.

Property/State	Gas	Liquid	Solid
Maturity	Unfinished, Work-in-progress	Draft, Request-for-comments	Final
Certification	None	Author	Author and Certifying Authoritiy
Persistence	Unwarranted	Web	Web and Digital Libraries

In more detail the main three properties abstracted away in this system are:

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- *Maturity*: despite being a basically subjective property, maturity is the most representative and intuitive of all of state properties. Gas objects are normally used for highly fluctuating work-in-progress and deemed with not enough maturity to be considered serious. On the other hand, liquid objects are considered to have all their basic knowledge or science in place but still undergoing some adjustments, while solid objects are considered mature enough for being candidates for extending human knowledge or science.

- *Certification*: refers to the person or entity that takes responsibility and, eventually, credit for the content of the object. For solid objects, both the author and a certifying authority (e.g. a publisher a board of reviewers, etc.) certify and assume responsibility for the artifact.

- *Persistence*: refers to the method used to guarantee availability of the resources over a period in time. In a web warranted persistence (liquid state) a web repository warrants that all liquid objects will remain available. On the other hand, in a "web and digital libraries" the object may be distributed and duplicated in digital libraries to further improve its persistence.

While published papers, hard-back books, among others are already existing and widely used examples of solid-state objects; gas-state artifacts are also ubiquitous if one also considers the content stored of personal computers (e.g. work-in-progress document, unordered notes). As such, one of the key points of this research is to enable and prove the utility of the introduction of the middle-level liquid state objects (e.g. request-for-comment, wiki-like discussions) as a way to improve the collaboration and early dissemination in the scientific process.

3.3 Version control and branching

Using the already defined structures it is possible to create semantic tags that are useful to identify and keep track of when an artifact is a version of other artifact. As in other version control systems, the same mechanisms could be used to determine whether an artifact was merged or split from previous ones.
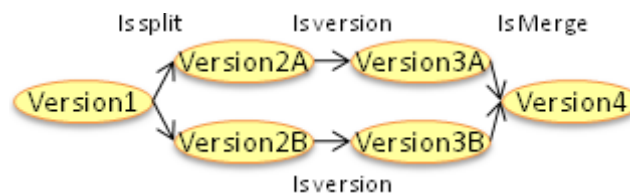

Figure. 3. Example of a version, branch and merging of the same artifact.

Figure. 3 shows basic examples of version, splits and merges. However, when considering the SKO layered structure system, interesting options are also enabled:

- *Part and wholes version control*: thanks to the clear identification of parts and wholes for each layer that the model includes, it would be possible for the version control system to evolve the individual components and the aggregated artifacts

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almost independently. Software families are a clear example of this type of part/whole evolution, and examples of these can be found at [12] and [13].

- *Layered version control*: as in the SKO model the artifacts are composed of several objects in different layers, it would be possible to version and change only some layers of a given artifact without introducing any changes to the rest. For example, changing only the presentation-layer objects of a document would create new presentations and styles of the same concepts; on the other hand, changing serialization-layer objects will create a different execution of the original artifact (with more or less the same concepts but different granularity/order).

It is the SKO model's ultimate purpose to become a multi-format aggregation resource that is not only able to access and aggregate content but also meta-content and discourse semantics from various proposed formats (like the ones in [14] and [15]). Implementing such system, would help to reduce the problem of having several big repositories that encode content and meta-content but are ultimately incompatible with each other. Furthermore, it would also provide a solid base for offering services like the ones from the Liquid Journals, Liquid Books and Liquid Conferences use cases.

The SKO's conceptual model is currently still evolving to cover the needs of the mentioned use cases. The latest work-in-progress (i.e. liquid) specifications and prototypes may be found at the project page[13]

4   The ResEval Assessment System

The Research Evaluation (ResEval) System is an example of a high-level service that operates interacting the with SKO module in the core of the LiquidPub platform. The main objective of ResEval is to provide the evaluation of the impact, use and in general the reputation of the different resources, in order to better support the search and navigation of the diverse Scientific Knowledge Objects.

4.1   Introduction to ResEval

The assessment of the quality and impact of research has always been a difficult task [16], due to the lack of common practices and methods that people could use to base their judgment on. Also, the proliferation of new fields and research areas (each with their own research methods) made this process even more difficult, since they demand the creation of standard procedures that need to be accepted by each of these communities. A research field already exists that works to address the mentioned problems and is called Bibliometrics.

The Bibliometrics ([17], [16] and [18]) field proposes, analyzes and defines methods for the assessment of most of the elements related to the scientific research

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[13] http://project.liquidpub.org/

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(e.g. authors, publications, journals, conferences, etc.). A number of applications for the assessment of scientific research have been proposed (e.g. Thomson's Science Citation Index, ISI Impact Factor), but most of them lack important features that are considered critical for their wide-spread application in today's world of scientific publication (see also [19]). For example:

- *Data completeness*: most of them do not have a complete and updated source of information, this accounts for evaluation results that are neither valid nor reliable.
- *Flexible methods*: the provided set of assessment methods are fixed and consequently tend to become outdated with passing of time.
- *Unavailability of an API:* the lack of an API(Application Program Interface) hinders the extensibility of the application.

In order to address the issues mentioned above, the applications should adopt new concepts and characteristics that appeared with the applications that are considered to be part of the "Web 2.0"[14].

There are two aspects of the applications and websites that are considered to identify them as Web 2.0 and that differentiate them from their Web 1.0 counterparts:

- *The Social aspect*: while the focus of Web 1.0 applications is to get more and more users, Web 2.0 applications focus on making users interact among themselves[15]. Examples of these user interactions can be seen in the wikis, forums and blogs scattered throughout the web.
- *The Technology aspect*: the appearance of web services, AJAX (Asynchronous Javascript And Xml) and design methodologies like the service-oriented architecture allowed the implementation of web applications that previously were considered as only possible in desktop environments[16].

Taking the previous into consideration, in ResEval we focus on the implementation of a Web 2.0 application for the assessment of the quality of research for the following reasons:

- *Accuracy and validity of the evaluation methods:* thanks to the improved interoperability provided by web services, the application will be able to use the information of the different external sources available on the web.
- *Flexibility and scalability of the provided methods:* thanks to the social aspect of Web 2.0 applications, the list of methods could be updated by the users of the application.
- *Extensibility of the application:* thanks to the provided web services and the use of a service-oriented architecture, the interoperability and extensibility of the application should be increased [20].

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[14] http://oreilly.com/pub/a/web2/archive/what-is-web-20.html
[15] http://www.techpluto.com/web-20-services/
[16] http://www.paulgraham.com/web20.html

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4.2 ResEval Architecture

The initial architecture for the ResEval module is an open and resource-oriented architecture described in the diagram in Figure. 4.
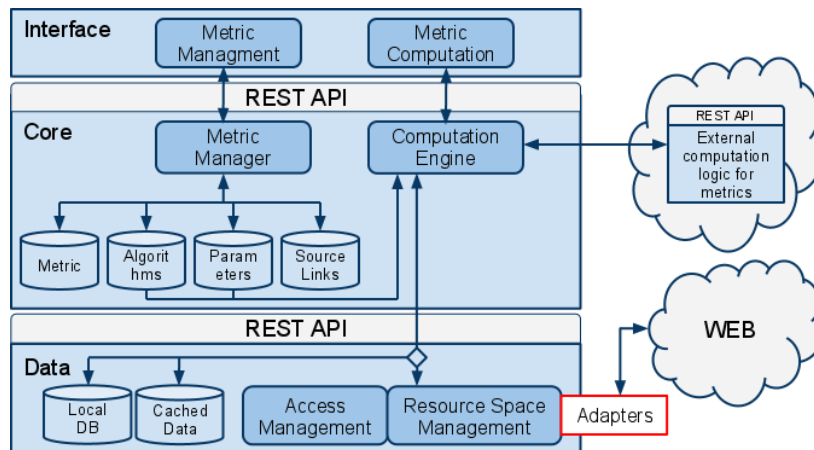

Figure. 4. ResEval architecture

- *Interface layer*: here there will be one interface that offers all the actions needed to create or manage metrics. The other will allow computing the defined metrics using the available options and information sources.
- *Core layer*: this layer stores and manages all the definitions and logic of the metrics. The core asks the data layer for all the information needed to compute a metric, then it actually computes said metric and sends the result to be displayed in the interface layer. Note that all of the functionalities provided by the core layer are available through REST services.
- *Data layer*: this layer is used to get the data needed in order to compute a specific metric. There are different sources where the application can get the data; internal sources, like a local database, or external sources found in the web

The general purpose of the ResEval system within the LiquidPub core platform is to provide, as it name implies, evaluation services that can be then used by each of the project's use-cases in the following way:

- *LiquidBook*: evaluation is here applied to the subcomponents of the artifacts (which could help in finding interesting material to reuse and include in the Liquid Book) and to the authors themselves (both in finding expert partners for the writing of specific Liquid Books sections and to support proper credit attribution of the most interesting contributions).
- *LiquidConference*: using the different metrics defined to evaluate authors, it can help to decide which authors to invite as panelists, moderators or reviewers for a LiquidConference.

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- *LiquidJournal*: improves its searching functionalities by applying some of the defined metrics to evaluate the retrieved resultset (e.g. getting articles about web services that have more than 50 citations or articles about data mining whose authors have at least an H-index [21] of 10).

At present there are two prototypes based on ResEval RestFul API. The first prototype provides a simple web application to query for the evaluation of research contribution and individual researcher using citation based metrics and can be used and tested at http://project.liquidpub.org/reseval/[17].

The initial web application implements (as plug-in) the following standards metrics for individual researchers: overall citations count; number of publications; average number of citations per publication; h-index; g-index. In addition, new pluggable metric for some novel indicators have been developed (by other students and researchers involved in the project), namely:

- *Signal to noise ratio*: it's the ratio between the number of publications that contributes to the computation of h-index and g-index, i.e. those that have received at least one citation and the total number of publications. The aim of this metric is to somehow estimate the quality of the work of a researcher compared to the number of publications he wrote.
- *Top citers*: it's a list of those that have cited the specified author the most. Users can click on the checkboxes to exclude one or more of them, in order to see how the indexes change without their citations. The idea is to see whether the citations come only from people "known" by the specified author (i.e. co-authors, himself) or, conversely, the author is cited by people from different departments, organizations, universities.
- *Top co-authors*: it's the list of those that more often have co-authored a publication with the specified author. Users can click on the checkboxes to exclude one or more of them. This aims to be an indicator of the independence of the author.
- *h-index and g-index* without self citations: self citations are subtracted to the total number of citations, then the two indexes are recomputed. This is used to see how much the self-citations weigh on the assessment of the specified author.

The second prototype is a group comparison web application, available at http://project.liquidpub.org/groupcomparison/. It allows users to create groups of researchers and to do comparison across and within groups. A group can be formed in various ways, e.g. finding all co-authors of a certain author, or considering all the full professors in a department. Once groups are created they can be compared considering e.g. average h-index, average g-index, number of publications, etc.

 Indeed, it is possible to compare two or more groups using the aggregate bibliometric indexes, as well as to compare scientists within the same group.

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[17] Please note that, for performance reasons, we queue every new requests; a new query will therefore be available only after an interval of time indicated in the graphical interface. We then store every query and provide the results of subsequent requests (of the same query) from our cache, allowing the user to decide eventually to update the data (i.e. launching a new query to the system and recompute the metrics).

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Moreover, when doing comparisons within a particular group it is possible to identify the most prominent scientists within the group.

5 Final Words

Each section of the paper has introduced the different components and use-cases of the LiquidPub platform and how they could be used to favor the scientific inclusion of developing countries. The following list offers a quick reference to the impact of the proposed approaches:

- *Makes scientific and technical knowledge easier to find*: enabling professionals, educators and struggling scientists to keep themselves competitive on their respective areas.
- *Bridging distances between experts/researchers*: allowing people to introduce, discuss and leave comments/annotations about scientific or technical resources regardless of their distance and origins.
- *Allowing new types of collaborations and contributions*: by providing a platform that it is able to keep track of authorship at the subcomponent level, thus enabling reuse and collaboration that would create new opportunities for contributing to global science. Furthermore, smaller units of contributions like data sets and experiments also become a possible contribution (as opposed of only full papers being accepted).
- *Helps the dissemination of ideas*: so that the work of everyone that has registered its scientific resources online is findable by the interested persons.
- *Provides a common framework for scientific resources*: further empowering smart search and navigation by understanding on several known formats for content and annotations, being able to link different representations of the same ideas, and different maturity states.
- *Provides quick and free assessment and evaluation of published material and authors*: this allows not only assessing individual contributions or authors but also groups of people, communities and, in the future, even countries. This information can be used by the researchers themselves or by the entities that regulate scientific grants, wanting to decide their investing strategies.
- *Allows finding and access of different types and maturities of scientific resources*: this would allow to find information in blogs or wikis (for the more innovative, albeit less stable ideas) or in journals and papers (for more mature and stable information) by using the same platform.

This paper introduced the general ideas and two of the components of the LiquidPub platform. The project itself is currently ending its second year, so it is expected that more information about the implementation of each of its components and validation of its various claims will be available during the third (and final) year of the project. Finally, the projects' webpage (http://project.liquidpub.org/) can be used as a hub for finding all additional content and also for contact information for collaboration options.

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