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Editorial

Maurer, Hermann

In this Special issue we have collected information from all over the word on how to preserve and use information in a digitized form.

I want to start on rather personal note: Ian Witten was a graduate student in one of my classes in the late sixties in Calgary, Canada. He built up an impressive career in both Canada and his home-country New Zealand, certainly becoming the best-known computer scientist in New Zealand, before his retirement, a short while ago. We only collaborated once for a longer period, when Witten spent a sabbatical in Graz. But somehow, we had, some 30 years ago, independent of each other, the same vision: digitized material should be easily and openly accessible. In that sense, we propagated free access to scientific results some 20 years before it became a main credo of research supported by the European Union. Witten concentrated on bringing this to libraries with his successful Greenstone project [1] in the early nineties. David Bainbridge describes this project and its success in paper 1, "*A Renewed Look at Greenstone: Lessons from the Second Decade*".

Just about the same time I started with the world first open source and free access journal JUCS [2], now also 25 years old and widely accepted.

It is curious that now, towards the end of my career I am returning to a new kind of library that colleagues and I are describing in the last two papers. Paper 9, "*Experiences Based on a Major Information Server*", discusses some basics, but paper 10, "*Investigating Interaction Activities in Digital Libraries: The Networked Interactive Digital Books Project*", gives a glimpse into the future of a system NID (Networked Interactive Digital Books) that will officially be released in spring 2020 and will allow combining books and papers into coherent collections concerning topics chosen by the users.

It is interesting that in addition to commercial applications which we do not discuss in this issue, digitized material was soon used for educational purposes as paper no. 2, "*Digital Materials to Support Learning: Success Stories in Teaching Computer Science*" by Andreas Bolin, and paper no. 3, "*The New Functions of OER Repositories for Personalized Learning*" by Tsuneo Yamada, show. How far one can use digitized repositories (and interactions) to help learning is shown also in paper no. 5, "*Computational Notebooks in Public Repositories*" by Daniel Speicher et al, presenting a combination of books, discussion forums, collections of notes, and papers. Paper no. 4, "*Preserving Cultural Knowledge Through Community-Lead MOOCs*" by Narayanan Kulathuramaiyer et al, gives a perfect example how culture can be preserved for large groups of persons through the Internet.

Paper no. 6, "*Towards 3D Digitization in the GLAM (Galleries, Libraries, Archives, and Museums) Sector: Lessons Learned and Future Outlook*" by Reimar Tausch et al, goes to the heart of digitization: explaining why and how artifacts of all kinds can be efficiently virtualized. Paper no. 7, "*Potential of Bots for Encyclopedia*" by Mirhet Saracevic et al, shows the dissatisfaction with searching for information by just using words or simple metadata and proposes the use of bots to help users, or to at least nudge them towards the area they are really interested in. In paper no. 8, "Insights to the State-of-the-Art PDF Extraction Techniques" by Ahmer Maqsood Hashmi et al, the idea is examined from a different point of view: how to extract relevant information from pdf files, a task that will grow in importance more and more.

In paper no. 9, "*Experiences Based on a Major Information Server*" by Namik Delilovic et al, briefly mentioned before, we are considering how to find information readily (as explained in some of the preceding papers) but also that a new phenomenon arises: we may not be able to present information any more in one way for all groups of users. The good old textbook is more and more rejected by younger persons, but graphics, considered trivial or stupid by older generations, may be the only way to convey information to younger ones. This seems to be the obvious consequence of the fact how fast society and technology are changing. In paper no 10, "*The New Functions of OER Repositories for Personalized Learning*" by Bilal Zaka, we claim that the era of traditional libraries (including digitized ones) is coming to an end: we should not see a library any more as a set of isolated untouchable entities,

but as a repository of information where, for any topic of interest, pieces of information can be pulled together from various books, webpages, and other documents. Also, why not allow users to make remarks in books readable only by some persons of designated groups, or why not start discussions, again controlled, so that negative effects like mobbing or promoting nonsense as happens in some social media, is not possible.

H. Maurer, hmaurer@iicm.edu, Graz University of Technology, Jan 2020

REFERENCES

[1] http://files.greenstone.org/others/Greenstone_history.htm

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

A Renewed Look at Greenstone: Entering the Third Decade

Bainbridge, David; and Witten, Ian H.

Abstract: The Greenstone Digital Library Software has helped spread the practical impact of digital library technology around the globe. As Greenstone enters its third decade, this article takes a renewed look at its development, the challenges that have been faced, and the lessons that have been learned in deploying a comprehensive open-source system for the construction of digital libraries internationally. In particular, we outline architectural changes in the software that have occurred over time, and highlight how the user interfaces have evolved to provide a more immersive, interactive user experience, made possible through advancements in the underlying web technologies.

Index Terms: Digital Libraries, Interface Design, Software Architecture

1. *Introduction*

It has been two decades since the name Greenstone was adopted for the emerging code-base that was, at the time, being developed under the auspices of the New Zealand Digital Library Project, and a decision made to distribute it under the GNU General Public License. Over this time the project's overarching aim has remained unchanged: helping spread the practical impact of Digital Library technology through the development and deployment of a comprehensive open-source system for the construction of digital libraries internationally.

Manifest through versioned releases of Greenstone, the software is not a digital library *per se*, but a tool that empowers others to build and distribute fully-searchable, metadata-driven digital collections of their own content, accessed from the web or removable media such as a USB thumbdrive or DVD. Examples range from OCR'd document collections focused on humanitarian development to audio- and video-based oral histories by indigenous peoples; from digitized Armenian rare books to born-digital archaeological reports from site digs; from historic early editions of musical compositions to institutional repositories that capture and distribute academic outputs.

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For further examples see:

www.greenstone.org/examples.

Although the NZDL Project, with associated software, stretches back to the mid-1990s, Greenstone itself was registered on SourceForge in September 2000. Since then, the software has been downloaded from practically every country in the world. SourceForge statistics record 220 countries, although this is an accumulated figure—some no longer exist, and others have emerged. The top five by total download count are (in order) India, USA, Vietnam, Ethiopia, and Argentina. Greenstone recently topped the 1 million download mark, including binary distributions, source code and documentation.

The drive for internationalisation was stimulated by partnerships with UN agencies—in particular UNESCO—and the Belgium-based Human Info NGO. Thanks to an online community of volunteer translators, Greenstone's web interface (which we refer to as the *Reader's Interface*) has been translated into 60 languages. The graphical interface for collection building and maintenance used by digital librarians, curators, and other content managers (the *Librarian Interface*) is available in 23 languages. At the time of writing the mailing list contains over 800 users, three-quarters of whom are on the "users" list and the remainder on the "developers" list.

On Greenstone's tenth birthday we reflected on what had been achieved in *A Retrospective Look at Greenstone: Lessons from the First Decade* [8]. The present article provides an update by describing the second decade of development and summarising key accomplishments. This is largely reflected in the move to Greenstone 3, which utilises the same collection-building code base as the earlier Greenstone 2 but includes a complete rewrite of the runtime system to take advantage of newer web standards.

We begin by detailing how the software has evolved, noting in particular pertinent architectural changes. Next we compare and contrast the end-user's experience of Greenstone 3's Reader's Interface with its forerunner. We then highlight two new features—the Document Editor and Greenbug—designed specifically to support the digital librarian when undertaking maintenance and management work *in situ* in the digital library. Finally we summarize key lessons learned.

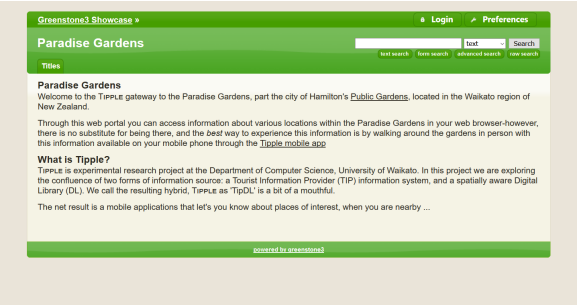

Figure 1: The *About this Collection* page for the Paradise Gardens collection using the default Greenstone 3 interface.

Figure 2: The same *About this Collection* page using Greenstone 3's halftone interface.

2. *From Greenstone 2 to Greenstone 3*

The core architectural decisions for the Greenstone 2 software were made in the late 1990s, which was very much a formative period of the web. Many web technologies that are commonplace today were in their infancy—or non-existent. We frequently ended up implementing something from scratch that got the job done.

A case in point is the configuration file for a collection. Back then, the XML format had yet to be invented! We created a bespoke textual file format in which each line began with one of a list of keywords that dictated how remaining text on the line was to be interpreted. Although we wrote detailed documentation describing what was needed to create collection configuration files and how to specify things in this admittedly arcane format, users were left to their own devices in entering the information in a text editor. The consequences of error were severe and, often, incomprehensible.

Today, an XML format accompanied by an appropriate XML Schema allows a range of text editors to support the creation of valid configuration files, including highlighting syntax errors. We return to this point in Section 2.5.

Having seen how web technologies have developed, our "roll-you-own" approach to the core components of the Greenstone 2 architecture seems appropriate for the time. Summing up this period of the project, we developed a suite of components and combined them into web-based workflows that are recognisable in today's web technologies—with the caveat that our inventions were form-fitted to the specific functionality needed in a digital library.

As the project moved forward, we reported on the burgeoning development of Greenstone 3 in [8]. Introducing research-led features into Greenstone prompted user reports of unforeseen problems on the discussion list, so Greenstone 3 was conceived as a purely research-based project in which to pursue new avenues. Built using the more established web technologies, backwards-compatibility was possible, but was not provided by a consumer-focused point-and-click graphical installer: a non-trivial level of IT skills was required.

Over time, however, the demands of maintaining two versions of the software outstripped our resources, and in *A Retrospective Look at Greenstone: Lessons from the First Decade* we noted that a decision to make Greenstone 3 the flagship version of the software had just been taken. Before that point, Greenstone 2 was promoted as the production version—with a graphical installer and comprehensive tutorials—and Greenstone 3 was the "bleeding edge" research-led version. Over a gradual transition process, Greenstone 2 was marked as deprecated, with releases focused solely on bug fixes, and Greenstone 3 built up to be the production version. The transition is now complete.

2.1 *Greenstone 3 Software Overview*

A graphical installer for Greenstone 3 was developed that set up a Tomcat web server with a servlet-based runtime system, in contrast to the Apache *httpd* web server with CGI scripts used by Greenstone 2. This required rewriting all 30 existing tutorial exercises for Greenstone 3. Developing the new installer helped us consolidate and generalise the in-house "release-kit" code that had been written to automate the generation of a software release, and Greenstone 3's backwards compatibility guaranteed that all the tutorial exercises could be expressed within the new architecture.

Strong adoption of mainstream web technologies has the enormous side benefit of being able, in our user instructions, to focus on the requisite steps and the reasons for them, rather than getting caught up in explaining the idiosyncrasies of in-house syntax. The number of tutorials has been increased to around 40 to reflect new features—such as changing the look and feel of the Reader's Interface by creating new graphical styles using the interactive (point-and-click) JQuery-UI Theme Roller.[1]

Figures 1 and 2 illustrate how different styles can be applied to the same digital library content. Figure 1 shows the *About this collection* page for the Paradise Gardens collection using the default Green-

[1] https://jqueryui.com/themeroller/

stone 3 Reader's Interface. It adopts the default sans-serif font of the user's web browser and, in keeping with the software's name, uses a mid-to-dark green background colour for the header and footer of each page served up by the system. Figure 2 shows a different look for the same page, with a bespoke colour palette and text display controlled by web fonts. Moreover, it includes Twitter and Facebook links, encouraging visitors to share what they are doing with others through social media.

To reconcile Greenstone 3's original aim of supporting research-led development with its role as the production environment, the concept of "extensions" was introduced. Extensions operate at the file-system level: the digital library set-up procedure looks for sub-directories of an *ext* directory and accesses their content as appropriate. Extensions can manipulate environment variables so that their functionality remains *in situ* on the file system (common in the case of build-time extensions), or else provide 'install' and 'uninstall' directives that modify the core code base (common in runtime extensions). In the latter case, recompilation of Greenstone is typically required.

The best way to see the differences between Greenstone 3 and 2 is through examples of the interface in use, which we provide in Sections 2.2–2.4. To appreciate these, it is useful to know something about the underlying software architecture, in particular the role of XSL Transforms (XSLT) [5].

A Greenstone 3 digital library is conceived as a modular network of services, where XML messages are passed around as a result of user-initiated tasks or interactions—typically performed in a web browser—or system-initiated tasks—such as automated testing. This gives the architecture sufficient versatility to meet research needs. The production version of the software is delivered by priming the default installation with services that implement the basic functionality of search, browsing, document view and user preferences, as in Greenstone 2.

To respond to web-browser user interactions, a "Receptionist" module applies XSLT transforms to XML generated messages returned to the browser. This transforms the message into XHTML, which the browser then displays. The transforms are determined by the digital librarian, which is how presentation and functional changes are managed. It is also possible to stipulate that the final XML message is expressed in JSON format [7], which is useful when delivering Web 2.0-configured interfaces. Further details of Greenstone 3's software architecture are described in [3].

2.2 *Reader's Interface*

The Reader's Interface is the web browser interface for end users of Greenstone digital library collections, and is quite distinct from the Librarian Interface, used by librarians, archivists and other managers of digital content to develop and maintain Greenstone collections. Greenstone 3's Reader's Interface is a complete reimplementation of the earlier version that maintains the core features of search, browse, document view, and user preferences, but places greater emphasis on presenting users with an immersive, interactive experience.

To convey a sense of the changes, we compare the Greenstone 2 and 3 versions of the Reader's Interface to the *Niupepa: Newspapers in Māori* collection. This is a collection of historic newspapers published between 1842 and 1932, primarily for a Māori audience. Based on a microfiche collection created by the Alexander Turnbull Library (part of New Zealand's National Library), it contains 17,000 digitized pages that have been OCR'd—mostly manually corrected by hand to fix transcription errors—to support full-text searching. 70% of the collection is written solely in Māori, 3% in English, and the remainder is bilingual. There are three main types of niupepa: government sponsored, Māori initiated, and religious.

Figure 3 shows Greenstone 2's *About this collection* page. It conveys in general terms what users can expect to find in the digital resource. In the case of *Niupepa* it provides the sort of details we have just given, and more.

Figure 4 shows the Greenstone 3 version. It contains the same information as its predecessor, but there are clearly visible differences—principally the page width and the elements displayed in the page header. It used to be common practice to expand web pages to the full width of the browser window—typically the width of the user's screen. But desktop screens have become wider, leading to very long lines of text, which is known to impact readability. Today's websites usually limit the page width, which is easy to control using Cascading Style Sheets—a web standard that gained traction starting around 2001 [4] and is now used throughout Greenstone 3.

The headers of Figures 3 and 4 both give access to the core features of search, browsing, search, and user preferences. However, with advancements in cross-browser support for visual and typographical effects, it is no longer necessary to use custom-generated images to achieve the desired visual effect as Greenstone 2 did—images that had to be generated for each language supported by the interface.

In Greenstone 3 the different ways to access a collection appear as a row of tabs, and the header includes a quick-search box, a common trend in contemporary website design. A button below the quick search box takes the user to an advanced search page.

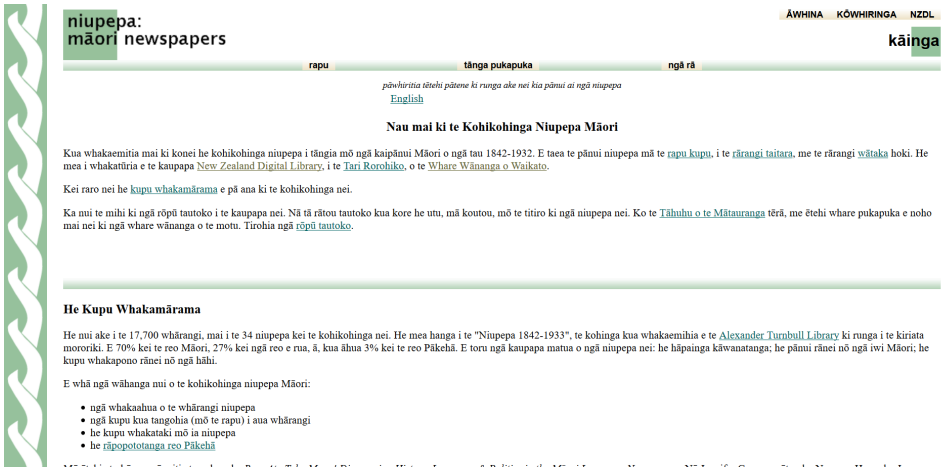

Figure 3: The *About this collection* page in Greenstone 2 for the *Niupepa: Newspapers in Māori* collection.

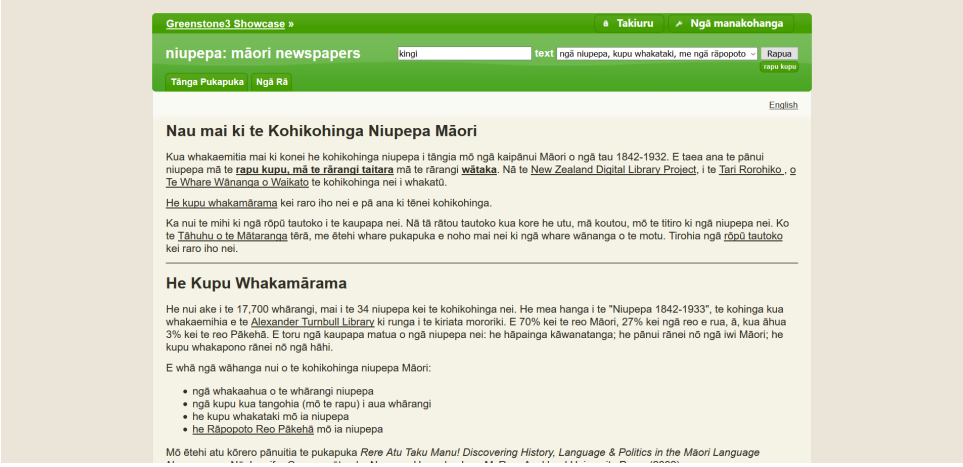

Figure 4: The *About this collection* page in Greenstone 3 for *Niupepa: Newspapers in Māori*.

Figure 5: Top-level browsing by series in Greenstone 2 for *Niupepa: Newspapers in Māori*.

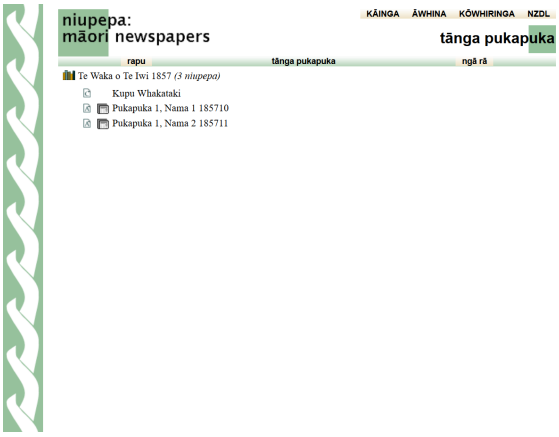

Figure 6: Drilling in to a particular newspaper title when browsing by series in Greenstone 2 for *Niupepa: Newspapers in Māori*.

2.3 *Browsing*

To illustrate the more immersive user experience that Greenstone 3 provides, consider the *browse by serial* feature of *Niupepa*. This shows all newspaper titles—such as *The Maori Messenger – Ko te Karere Maori* and *Te Waka Maori o Ahuriri*—sorted alphabetically, from which one can explore particular titles to determine what editions of that paper the collection contains, listed by volume and number. Figures 5 and 6 show how the mechanism used to work, and Figure 7 shows the new approach.

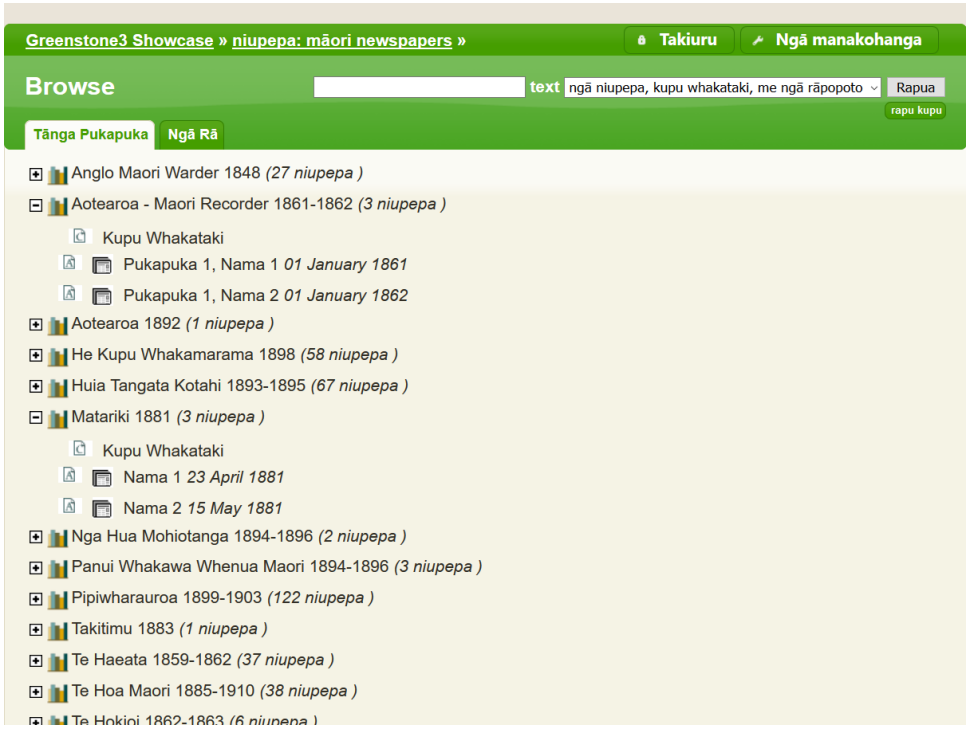

Figure 7: AJAX-based Interactive browsing by series in Greenstone 3 for *Niupepa: Newspapers in Māori*.

In Greenstone 2, a new page is loaded every time a user interacts with the browsing hierarchy. Figure 5 shows the list of titles, and clicking one—*Te Waki o Iwi*, for example—to view its editions causes the browser to load the page in Figure 6, which displays the newspaper's title, and, beneath and slightly indented, a commentary on that paper (if available) and the editions published (two, in this case).

With the emergence of AJAX interaction with the Document Object Model (DOM) in Web 2.0 [2], the browsing feature has been redesigned to provide a better overview of the information and reduce the volume of data transmitted over the network.

In Figure 7 we join the user partway through their interaction. Initially they see the same top-level "bookshelf" icons for newspaper titles as before. But when they click on one, instead of reloading the entire page as Greenstone 2 does (retransmitting all the header, footer and page formatting information), Greenstone 3 makes an AJAX call for just the items under that bookshelf, which it adds to the page using DOM manipulation. Users can still see the full range of titles, and—as has occurred in the Figure—continue their exploration of other titles, opening up further bookshelves, while retaining an overview of all titles.

Clicking an opened bookshelf returns it to the closed state. The browser remembers which bookshelves have been opened, so that if a user further explores another newspaper title—which causes a full page load—and then navigates back, any previously opened bookshelves are restored. Since the AJAX calls need less network data to operate than in Greenstone 2, the new interface feels more responsive. The results of these AJAX calls are cached, so that if the user, browsing around, opening and closing folders, ever returns to a previously-opened bookshelf, the interface skips the network call and shows what it has already stored for that node.

Another (unconnected) aspect of the new interface is the use of "breadcrumbs" [6], a feature designed to help users keep track of where they are in a website—in this case a Greenstone library. The breadcrumb is located in the page header, shown at the left of the very first line of text. In Figure 7 it is *Greenstone3 Showcase » niupepa: māori newspapers*, the name of the library being visited (*Showcase*) followed by the collection being accessed. If a user were to view one of the newspapers the breadcrumb would change to *Greenstone3 Showcase » niupepa: māori newspapers » Tuhinga* (or, in the English interface, *Greenstone3 Showcase » niupepa: māori newspapers » Document*). This trail of breadcrumbs occurs throughout the digital library.

2.4 *Document View*

Figures 8–11 illustrate how the document view has changed between the two versions of Greenstone, again using the *Niupepa* collection as the example. In Greenstone 2, the "document view" for an OCR'd scanned image provides buttons that display the document's text (Figure 8), a preview image (Figure 9), and the full-size version (Figure 10). Users can click forward and backwards to access adjacent pages, or enter a page number into an input box. As when browsing, each of these interac-

Figure 8: The Greenstone 2 text view for a page of *Niupepa: Newspapers in Māori*.

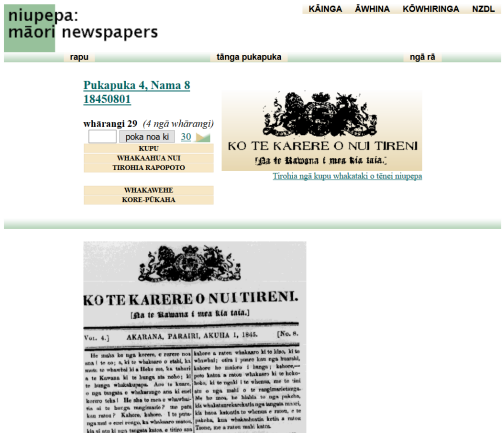

Figure 9: The preview image view of the page in Figure 8.

tions invokes a page reload.

Greenstone 3 brings all this—and more—together in a single integrated view. Figure 11 shows the main scanned-image document view. On the right is a page-preview table-of-contents area, enlarged in Figure 12, which is styled in the fashion of popup preview windows often shown when printing a document. When the user accesses a newspaper in the collection, thumbnail images of all its pages are (asynchronously) loaded. Clicking on one displays the page at screen resolution in the main interface area; alternatively a sequence of contiguous or non-contiguous page numbers (e.g., 1, 6-9) can be entered into the text box underneath the thumbnails and the main page dynamically updates appropriately.

The controls above the preview area in Figures 11 and 12 determine whether the page text, the screen-view image, or both, are shown. A magnifier is included that operates on the screen-view image as the cursor moves over it; alternatively, a full-screen view can be obtained (using the canvas-on-easel icon) that occupies the full browser window rather than the limited width used in the other displays, so

Figure 10: The full image view of the page in Figure 8.

that users can see as much of the high-resolution image as possible.

The thumbnail images are displayed horizontally but the screen-resolution/text-displayed pages they relate to are organized vertically. This part of the interface operates in the same way as the hierarchical browsing view described above. AJAX calls are made for just those parts of the document required for display, again increasing the interface's responsiveness. As before, caching is used to avoid making network calls for repeat visits to parts of the document.

As users continue to explore pages of a newspaper the length of the vertical display grows. To avoid having to repeatedly scroll up in order to interact with the page-preview control area, a "tear-away" feature is provided that removes it from the vertical page display and attaches it to the upper right-hand side of the page. If users find that the page-preview control area encroaches on their screen space they can minimise it by clicking the close icon in the top right-hand corner of the control panel.

2.5 *Librarian Interface*

Greenstone 3 retains Greenstone 2's "Librarian interface" (GLI), a Java application that creates, develops, and helps maintain a digital library. GLI has been re-coded to utilize the new XML collection configuration file format. Also, the *Format* tab, through which presentation details for the collection can be specified, has been updated. In Greenstone 3 format statements are expressed using XML syntax, and the graphical user interface has been changed to use the *RSyntaxTextArea*[2] component rather than Greenstone 2's generic freeform *TextArea*, bestowing the syntax error highlighting feature that we mentioned earlier as a key benefit of using new standards.

GLI's purpose is to provide a graphical user in-

[2] https://bobbylight.github.io/RSyntaxTextArea/

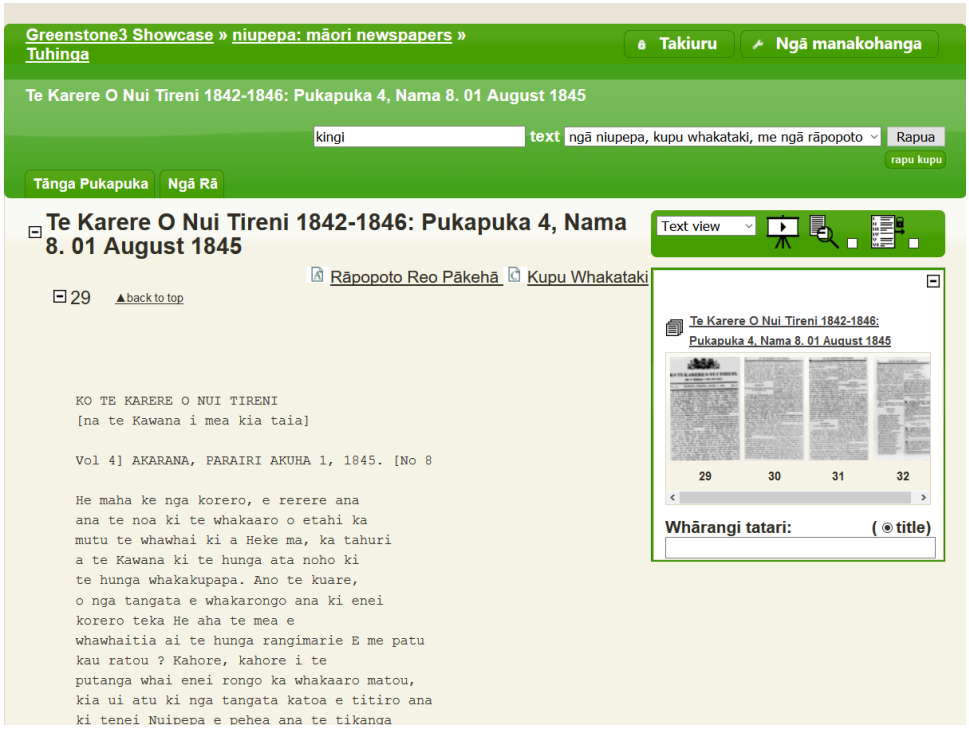

Figure 11: Greenstone 3's main scanned-image document view.

Figure 12: Enlarged excerpt of Figure 11 showing the interactive preview area.

terface for controlling all aspects of the design of a digital library collection. This is particularly useful in the early stages of collection development, but becomes cumbersome when performing on-going maintenance. For example, if a librarian notices an error in a document's metadata when browsing on the web, to correct it they must (i) start up GLI and (ii) relocate the offending document through that interface, which only shows a file-system view, before (iii) accessing GLI's *Enrich* tab to correct the error and update the digital library.

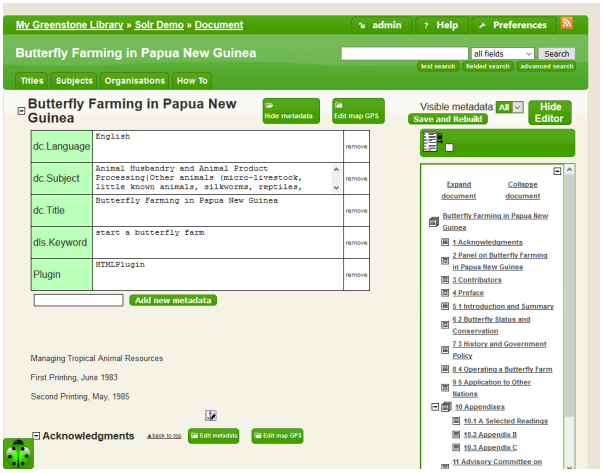

Figure 13: The in situ document text and metadata editor in action.

To rectify this, Greenstone 3 contains editing capabilities that operate within the browser, giving direct ways to manage and maintain collections. The librarian mentioned above clicks on a *Login* button (*Takiuru* in the Māori interface shown in Figure 11) and accesses the "Document Editor" shown in Figure 13. This wiki-like editor gives authenticated users access to sections of the document that they can edit and save. In addition, for each section they can click an *Edit Metadata* button to reveal a table of the metadata assigned to that part of the document.

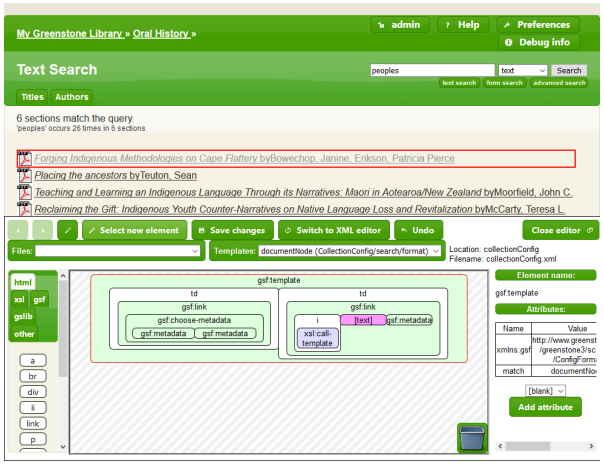

Figure 14: Greenbug in action.

They can correct values, remove them, or add new ones, and save all this to the digital library.

The Solr[3] indexing tool has been included in Greenstone 3 as an option for document ingest, and this supports spatial search. GPS metadata embedded in documents are extracted and used to provide a proximity-based search service. In the Document Editor, an *Edit Map GPS* button appears beside the edit metadata button, which invokes a Google Maps component through which regions and GPS markers can be entered.

Figure 14 shows another type of *in situ* editing that Greenstone 3 supports, in this case to control the overall structure and functional features the library provides. It was inspired by Firebug, a Firefox extension for web developers who wished to inspect the underlying structure and state of web pages—a capability that is now standard in all major web browsers. Web inspectors help developers trace the reason why something is not displaying the way it should, and allow them make changes to the underlying syntax and immediately see their effect.

The "Greenbug" editor [1] allows one to inspect the state of pages served up by the digital library software. As in Firebug, the user starts by selecting an element. As they move around a library web page, a highlighter box follows the cursor, snapping to elements that they hover over. For example, the upper portion of Figure 14 shows a Greenstone search page with the highlighter box snapped over the top item in the list of search results. The lower portion gives an interactive, editable representation of the structure that has produced that part of the page. Whereas Firebug shows the HTML elements that are responsible for the selected part of the page, Greenbug shows the underlying XSLT elements. These elements can be edited, and the edits take effect immediately in the page displayed above. Moreover, Greenbug goes further than Firebug (and other web inspectors) by allowing users to save their changes. This is possible because it is closely integrated with the underlying Greenstone 3 system. By first ensuring that users are authenticated, the Greenbug code is granted access to more trusted parts of the service-based API—such as the ability to update the XSLT files used by the digital library.

[3] https://lucene.apache.org/solr/

3. *Insights and Lessons Learned*

What has been learned in Greenstone's second decade?

Hits and Misses. A recurring criticism was that all Greenstone 2 collections are displayed on the same top-level page. Unrelated sets of collections can only be kept separate by installing a new instance of Greenstone on the same server. Greenstone 3 addresses this issue by introducing the notion of *sites*, which gives precisely this ability within a single Greenstone installation. A further layer of abstraction, *interfaces*, allows the curator of the digital library installation to select or develop different look-and-feels, which can then applied to individual sites. These new capability have proved to be extremely popular with librarian users—a hit!

Another criticism was the cognitive effort required by developers to learn how to control the presentation and structure of their digital library installation. Format statements and macro files in Greenstone 2 were the bane of their lives! We developed both of these from scratch, and had to provide a great deal of documentation and tutorial support, in the form of exercises, to educate users. Greenstone 3 unifies these two aspects through the use of the XSLT web standard. However, we now get complaints that this is more verbose than the original format statements and macro files, and the inheritance mechanism that operates across collection, site and interface makes it hard to find the appropriate XSLT rule to edit. The introduction of Greenbug should alleviate this concern. Hit or miss?—time will tell.

Learning Greenstone. We previously developed an extensive set of tutorial exercises, which are the principal means by which people learn how to use the software. However, during live tutorials it is apparent that participants often struggle to extrapolate from the exercises to meet their own needs. We now believe the cause to be the "point-and-pick" nature of the tutorials, which was originally adopted to enable people to work independently and at their own pace. To rectify this we plan to append open-ended sections to each tutorial that supply a fresh set of files and metadata, just like what the user has been working with, accompanied by more general instructional steps. For example: *Build the HTML files into a collection with a Browse by Title feature. For HTML pages where the automatically extracted title does not appropriately reflect the document, manually assign a better one.*

Reluctance to change from Greenstone 2. Organisations and users who have established Greenstone 2 installations and operate them with minimal (or no) funding tend to stick with what they have working. While we understand the reason—if it ain't broke, don't fix it—we regret that these users cannot take advantage of the significant new features that Greenstone 3 provides. Luckily, an unanticipated consequence of the Greenstone 3 decision to continue to use and extend the Perl-based Greenstone 2 code for ingesting documents and metadata (such as enhanced processing of PDF files) is that improvements here also benefit those who have stuck with Greenstone 2.

Documentation bottleneck. It is always difficult to provide an appropriate level of documentation for users with a wide range of skill sets, and this is something that our small developer team struggles with. To help offset this, from the very beginning of Greenstone 2 and throughout the development of Greenstone 3 we have consciously designed and used data structures that are self-documenting.

This works well at the micro level. For example, when a GLI user is deciding how PDF documents being ingested into a collection should be processed —should keywords, for example, be automatically assigned based on the full-text of the document?— all available options available are displayed, along with tooltips translated into the language GLI has been set to use. All this is programmatically generated by Greenstone.

Concerning configuration control at the macro-level—such as whether or not a map view is shown when browsing by title, for example—we have begun to consciously include what we refer to as "configuration setting breadcrumbs." This extends the breadcrumbs notion introduced earlier to deliberately incorporate settings in a configuration file that are redundant but are useful for others to find—for instance, including an XML element that explicitly assigns a default value to a variable even though it is not necessary for this value to take effect in the code; or including a commented-out block of configuration file syntax that achieves an effect different to the default behaviour, to demonstrate possible alternatives. This approach complements the idea of self-documenting code in enabling self-discovery.

4. *Conclusion*

We have reviewed developments and experiences that have occurred in the Greenstone digital library software's second decade, complementing our previous article on the first decade [8]. New statistics on the user base highlights Greenstone's increased international reach, notably the number of countries where the software has been downloaded (220) and the number of languages the interface has been translated into (60). We have described some of the technical accomplishments and interface advances in Greenstone 3, which has become both the flag-ship production version of the software and the framework in which we conduct our research. Finally, we discussed some of the lessons learned.

In terms of the wider picture, we still struggle with the tension between research-led tools and production delivery. We have had to curtail the routine inclusion of novel tools developed in our research programme into the Greenstone code base, because of the burden it places on the development team in supporting multiple operating systems. Instead, we now favour the development of web-based demonstrations embedded within Greenstone 3 that show off its versatile software architecture, postponing any decision about bringing them into the distributed version pending an assessment of the level of interest in the result.

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Digital Materials to Support Learning
Success Stories in Teaching Computing Science

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Abstract: ***Technology has a deep impact on everyday life of most people today, and computing science, information and communication technologies, and digital media are finding their way to education, too. The use of technology and digital materials is, however, a matter of ongoing debate, and educators are called upon to decide whether and when to use digital materials or not. At the department of informatics didactics in Klagenfurt, we developed our own teaching approach and do have a rich experience in the use of unplugged and plugged activities in the classroom. This paper gives some background information about our learning approach and shows, through three examples, how digital materials can be introduced successfully at all levels of education, from elementary up to university level. It also shows that digital materials, when used appropriately, allow for broader methodological approach and stimulates more differentiated way of teaching.***

Index Terms: ***Neurodidactics, Computer Supported Learning, Digital Materials, K-12 education***

1. Introduction

At the beginning of 2018, the European Union (EU) Commission presented the Digital Education Action Plan [1]. It outlines how the EU intends to support educational institutions and education systems regarding digital transformation. According to the Commission, the development of relevant digital competences is urgently needed in the age of rapid digital change, both professionally and privately. The Action Plan focuses on the use of digital and innovative educational practices and has three priorities: (a) making better use of digital technologies for teaching and learning, (b) developing relevant digital competences and skills for the digital transformation, and (c) improving education through better data analysis and foresight.

The action plan stimulated a lot of projects in Austria and in the EU, but digital readiness in education requires knowhow and involves adaptation and change. Schools, universities and training institutions in Europe are diverse concerning equipment, teacher skills and varying approaches in using technology. It will take some time to close all the gaps, and, even more, to have enough digitally skilled educators. Digital competence is part of the revised European Reference Framework of Key Competences for Lifelong Learning [2], which all citizens should have … but being digitally competent is more than just being able to use technology appropriately [3]. As best-practice examples are not that wide-spread, and as further education of teachers still needs some time, debates on the use of new media and digital devices are continuing [4, 5].

The objective of this paper is to demonstrate that the use of digital materials or digital learning resources, when done appropriately, can be an enrichment for teaching at any school level. Even more, it also shows that by using digital learning resources, classroom interventions can help stimulating the learning brain. For this, we briefly introduce our brain-based teaching approach COOL-Informatics [6] and show using some examples at the primary school level, the secondary school level, and the University level, how the use of digital materials helped us in implementing successful learning strategies. Furthermore, we report on how accompanying school teachers' resistance to the use of digital materials decreased.

This contribution is structured as follows. Section 2 introduces the use of digital materials in an educational setting, and it also explains our brain-based teaching approach called COOL-Informatics in some detail. Section 3 presents three scenarios where teaching is supported using digital materials. Section 4

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reflects on the benefits and points out arguments for an improved learning experience, whereas Section 5 concludes with a summary and the implication on the way we use digital materials in our own classes.

2. BACKGROUND

2.1 Digital Learning Resources in Education

The terms “digital learning resource” and “digital material” are used mutually in this paper. They refer to materials or digital artefacts included in the context of a course or interventions that support the learner's achievement of the described learning goals and include graphics or photos, audio and video, simulations and animations or even prepared or programmed learning modules. But even though that there are a lot of opportunities, as an educator, we need good arguments for the use of digital materials.

As mentioned above, the impact of digital materials is still rated contradictorily. These contradictions go back to the fact that the effective variables of using digital technologies in the learning process are difficult to identify and the relationship between learners and the medium of learning is very complex. It still is not sure that digital materials have a direct effect on learning processes and outcomes in the sense of a cause-and-effect relationship. Rather, various factors, such as the acceptance of digital media used by learners and teachers or the self-learning competences of learners, might influence the effect of media and materials in the learning process. Kerres [7] postulates that digital materials do not directly affect the learners but are individually processed by them, which can be decisive for the effect of the digital medium.

However, he further assumes that digital materials have an immanent effect due to their media form (e.g. certain technical characteristics). Thus, certain situations can increase the motivation to learn and bring about a more intensive learning behavior (through visualization, simulation, interactivity, etc.). The learning content, learning tempo, and temporal and local planning of learning can usually be organized by the learners themselves. At the same time, digital materials also represent a "raw material" in that they open creative leeway that can be shaped by a media-didactic concept. In this way, digital materials influence their users.

Although no reliable statements are to be found in literature about the direct effect of digital materials in the sense of a cause-and-effect relationship so far, they at least have "immanent effects”. These immanent effects or potentials influence learning on several levels [8, p.29] (translated from German):

1. Digital materials enable a more self-organized learning and educational process in all dimensions by enabling self-organized actions and interactions in the generation of knowledge, in the exchange of knowledge and in learning from existing knowledge sources.
2. Social networks or other applications (e.g. WIKIs, social media video portals, blogs, etc.) in which texts, images or videos are shared with other users, enable community building, networking, and cooperation with other people or organizations with the same thematic background. In this way, experiential learning in professional and nonprofessional contexts can be supported by digital learning resources, too.
3. A reflection of work and learning processes - and therefore learning to learn - can be supported by e-portfolios or blogs in which one's own work and learning progress is documented and reflected.

With these findings, educators should have enough reasons for introducing digital materials into their lectures. But also, children seem to be in favor of new technologies. In 2016, Deloitte published the Digital Education Survey [9] that analyzes 2,800+ responses from demographically-diverse teachers, parents, and students in the US. The study showed that 90 % of all children use digital learning materials at home and 2/3 start by the age of 5. And even more interesting, 73 % of the children say more access to digital material would increase their time spent learning over the summer.

So, motivation and new possibilities are already a strong reason for the use of digital materials. And, with the advent of neuroscience and neurobiology, there are additional reasons for having digital content available to supplement our traditional classes.

	Neurodidactical principles	
	Teaching and learning methods	***Neurodidactical basis***
1. Discovery	• Solution-based learning [10] • Observational learning • Step-by-step instructions and tasks • Video tutorials, Hands-on, Minds-on • Learning with all senses	• Pattern recognition • Mirror neurons • Individual learning rhythm • modality / multimedia effect
2. Cooperation	• Team and group work [11,12] • Peer tutoring and peer teaching, [13,14] • Pair programming [15,16] • Cross-curricular learning • Project-based learning	• "A joy (=knowledge) shared is a joy (=knowledge) doubled." • Recall = re-storage in long-term memory • Integrating individual needs, talents and competences as well as practical relevance
3. Individuality	• Competence-based learning • Questioning, [17,18] • Self-organized learning with compulsory and optional tasks	• Connecting new information to previous knowledge, • Considering individual interests, needs, tasks, methods and learning rhythm
4. Activity	• Hands-on, Minds-on • Learning by doing [17,19] • Learning by animation, simulation and playing [20,21] • Learning by playing and designing games (creative learning)	• Knowledge must be newly created (constructed) by each learner (= constructivism) • Learning is an active process (= progressive education)

Table 1: The four principles of COOL Informatics [6]. Every principle is connected to a neurodidactical

2.2 Brain-Based Teaching

Using imaging techniques (e.g. fMRI) in cognitive neuroscience and neurobiology, new insights into the functioning of the brain were gained, which, to varying degrees, now also find their way into school practice. This new scientific direction is called "Neurodidactics" [22, 23, 24], and already in the 1980s, brain-based education became popular in the Anglo-American region [25].

Brain-based teaching attempts to translate neuroscientific findings into didactically concrete recommendations for the design of teaching. As such, it can be understood as basic, applied, and practice-oriented science. In the practice-oriented field of neurodidactics, for example, practical concepts, interventions, and recommendations for action are derived from models. As there are too many factors contributing to good teaching [26], and as the learning brain is complex, the field of brain-based teaching is also not uncontested. Up to now, neurosciences alone cannot guarantee successful teaching at schools or universities, but the insights provided into the possibilities and restrictions of the learning brain help more and more in explaining why some learning environments support learning and others do not. Caine and Caine [23] summarize a lot of issues that must be considered when teaching according to neurodidactic principles. Overall, students need the opportunity to gain concrete experiences. Learning processes that are integrated into social situations are more effective, as is the consideration of interests and ideas. The connection with previous knowledge is a central component of the learning process and positive emotions lead to more effective learning. Students understand the connection between individual details and the whole, which helps them to remember details better. In addition, the time for reflection improves learning (consolidation). Students learn better by combining information and experience. The recognition and integration of individual differences promotes learning processes. Students learn better through a supportive, challenging environment and the consideration of individual competences is of great importance.

At our department, we developed a teaching approach called "COOL Informatics" [6], which

is based on neurodidactical principles. The acronym COOL, of course, has special meanings in the context of “COOL Informatics”, and it can be translated as follows:

1. “Cool” means motivating, interesting, fun and effective.
2. “COoperative Open Learning” is an Austrian teaching model [27] that offers thematic, methodic, and institutional openness as well as cooperation on different levels and between different subjects.
3. “COmputer-supported Open Learning” refers to all forms of technology-supported learning, like CSCL (Computer-supported Collaborative Learning), E-Learning or Mobile Learning as well as eCOOL, the E-Learning variant of the COOL teaching model.

“COOL Informatics” is not simply combining all these fields to one approach, but it goes one step further. On the one hand, it extends the aspect of computer-supported learning to “computer science-supported” by implementing core concepts of informatics in other subjects wherever possible and reasonable (e.g. by comparing algorithms and the description of the way to school). On the other hand, it gets a new framework and a bases for neurodidactical principles. Corresponding to different meanings, the theoretical background of the “COOL Informatics” approach includes numerous teaching concepts and methods as well as a wide range of related work. It includes some corresponding and effective teaching and learning methods as well as related neurodidactical elements.

An overview of the four principles can be found in Table 1. It shows that the principles encompass “Discovery”, “Cooperation”, “Individuality” and “Activity”, and later on in Section 4, the relationship between these principles and the use of digital materials will be discussed in more detail.

The COOL Informatics concept forms the basis for different projects at our department and has its roots in projects like “Experiencing Informatics” [28] (which was also inspired by CS-unplugged [21]). COOL-Informatics now is one cornerstone of our “Informatics-Lab” (“Informatikwerkstatt” in German), a workshop that is open to the public and to schools and that is also used for our University’s teacher training and for the further development of STEM and non-STEM teachers. Since 2015, we had more than 14.000 attendees in our workshops and events and, in addition to scientific support [29], we provide a Creative-Common-based and rich set of materials (including the related didactic concepts) to all users of our workshops and partners [30]. Stemming from the experiences with elementary school children, secondary school pupils, and students, this paper now shows three ways of successfully using digital materials in education and relates them also to their neurodidactic background.

3. Experiences with Digital Materials in Education

3.1. Digital Materials at the Elementary and Primary Level

Whereas digital materials are already standard in higher education (mostly in STEM-related fields) at our Universities in Austria, especially elementary and primary school teachers are still confronted with arguments for and against the use of new media in teaching and educational accompaniment. Myths, educational doctrines, but also technological hurdles complete the picture. This situation differs from country to country (not all of them do have curricula focusing on computing science or ICT from the elementary level onwards, (see the work of Pasterk [31] for more details), but in all the cases one has to ask the question, if and when the use of technology does make sense.

In the year 2018, our department launched two projects that aimed at conveying the image of computing science correctly. The first project deals with computational thinking and is called “The Elementary Beaver”. It focusses on children age 4 to 7 and tries to break down typical beaver contest examples, which supports the learning of computational thinking skills, to the elementary level. The second project is called “Informatics in the Park”, and it is part of an international price-winning [32] initiative in collaboration with a science and technology park close to our University. It aims at providing a continuous computing science curriculum from elementary to secondary school level. The design of our interventions and modules not only followed COOL informatics but also stick to the principle of using digital technologies only when necessary or when there is clearly a chance to extend the “methodical treasure chest” of the related pedagogues.

Figure 1: (Left) Children following an interactive guide for training step-by-step instructions. Pictures, sound, and animation are possible (Right) In the front: taken from the beaver contest 2016, an application for experimenting with water pipes and valves to support learning computational and algorithmic thinking. (Both pictures copyright by “Informatikwerkstatt, AAU Klagenfurt”)

In the first step in both projects, the pupils got in contact with digital devices like cameras and tablets. They played around with recording functionality, produced a diary and finally used digital materials to work on problems (see Figure 1, left side). It turned out that both, the creation of digital artefacts and the use of digital artefacts was key to success.

The Bebras contest and, with it, hundreds of Bebras examples are designed for children age 8 and above as they assume reading and writing skills. In the Elementary Beaver project, we managed to break down 80 % of these examples to age level 4 to 7, but partially needed digital materials to do so. Whereas a lot of examples can be implemented in an unplugged manner (as board games, activity games), some would require expensive materials or cannot be realized in a safe manner. The watering system is such an example (see Figure 1, right side). It trains logical thinking and is somehow also an abstract representation of a circuit. The valves are the switches - with the two positions "open" and "closed". According to the input funnels and the switch positions, the information "water flows" and "water does not flow" move through the circuit - down to the flowers. Electronic devices contain electronic circuits through which electricity flows but creating such a system in real life with pipes and valves would have been fun, but not feasible at the elementary level – using digital materials however, this was easy to implement.

Although the teachers involved were initially cautious, they found the use of digital materials in both projects to be a strong enrichment of their classes and they began to make use of them. Even more, as they noticed that digital materials are not replacing but extending their collection of materials, they started asking us for implementing new applications. For the children, on the other hand, the materials were fascinating and, first driven by curiosity, they began to get more involved with the artefacts.

To summarize, in both projects at the elementary and primary school level, we are focusing on observational learning, step-by-step instructions and tasks, short video tutorials, hands-on, and learning with all senses, self-organized learning with compulsory and optional tasks, learning by doing, learning by animation, simulation, and playing. A lot would have been possible in an unplugged manner, but especially the use of digital materials enabled us to reach more children at the same time and to implement examples in an age-appropriate way, following the interests of the children and without requiring reading and writing skills.

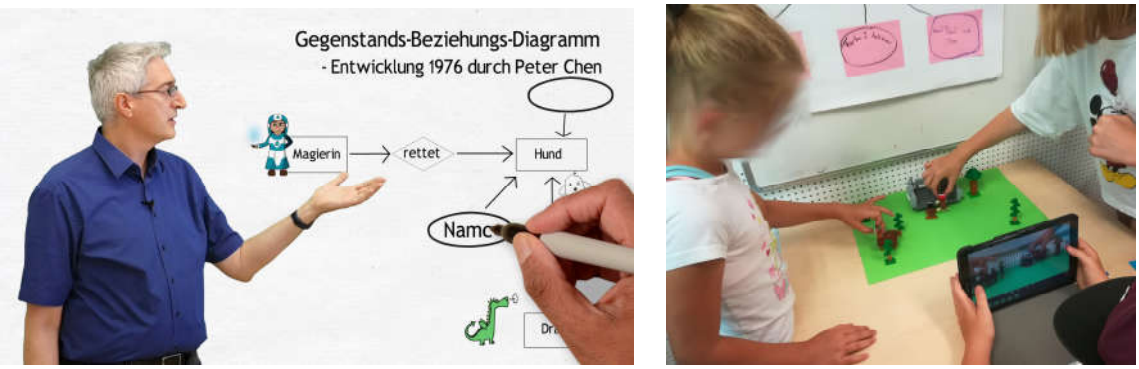

Figure 2: For a lot of topics we do have videos for teachers and/or for pupils. (Left) For teacher training, we are using a video showing how to introduce modelling techniques to children. (Right) The children are using paper/pencil and digital materials to design their stories. After modelling, they utilize stop-motion techniques to tell their stories. (Both pictures copyright by "Informatikwerkstatt, AAU Klagenfurt")

3.2. Digital Materials at the Primary and Secondary Level

As mentioned above, our department runs a project called "Informatics-Lab". It is a workshop open to the public and available for school-classes and in-service teachers as well as our teacher training students. The workshop covers a lot of topics from the field of computing science, like coding, hardware, logic, modelling, robotics, and safety and is also the driving factor behind events like the "Childs-Congress" [33], IT-camps and much more. Our plugged and unplugged materials are available from the end of primary school to secondary school level, but a lot of them are designed in an interdisciplinary manner which in turn makes them very successful among our partners. Schools from all over Carinthia are booking units, and students from our teacher training program do have the opportunity to train their skills.

With about 3.000 – 3.500 attendees a year sustainability is very important, and without the use of digital materials this would not have been possible at that size. An increase in skills, self-concept and attitudes is easily measured by an online questionnaire (c.f. project KAUA [29]) but delivering the content to the children aged 8 up to 18 is very demanding. The reason is that the pupils visiting our events and workshops differ in age and thus previous knowledge, their school-type and also their interests. In order to be successful, flexibility in tasks, materials and also in the didactic concepts, is a must. In order to deal with these issues, our teachers do have training materials and templates available online, and a lot of tutorials, step-by-step guides and quizzes are implemented in a digital manner in order to deal with visitors in full-class-size. During the past couple of years quite a lot of materials and guidelines are created. They are checked according to gender issues, their interdisciplinarity, and when they have successfully been implemented in the classroom, they are uploaded to a repository for broader use.

According acceptance among in-service teachers, we soon learned that they needed examples of how to use the materials, and so we started to record successful classroom interventions and now provide them as videos to our partners but also to future teachers (see Figure 2, left side). These videos not only contain background information (also as subtitles and a PDF transcript), but also examples and recordings of real classroom situations. Qualitative feedback shows, that teachers prefer this variant compared to conventional collections of materials or textbooks.

According to our younger visitors, digital materials are "naturally" mixed with all other types of materials. When modelling is a topic, paper and pencils are used as well as clay and/or LEGO bricks and characters. This is continued by either creating small stories using stop-motion (see Figure 2, right side), or by utilizing modelling tools on a laptop or tablet. With that, finally, objects or scenes are printed using a 3D printer. Without digital materials, only part of the creation process would have been covered. With digital materials the pupils experience the possibilities but also the limits of new technologies, but always have the feeling that their use is not artificial and on purpose.

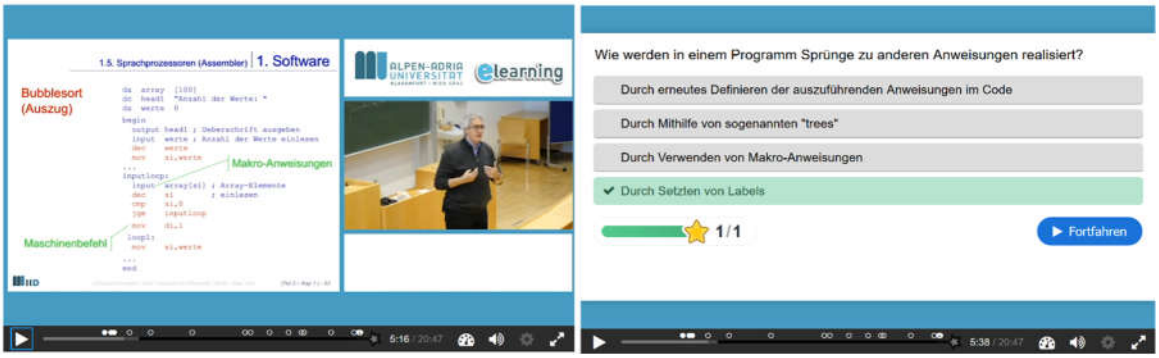

Figure 3: H5P Video explaining and testing for the functionality of an assembler. (Left) The recording is enriched by the slides used in the course. (Right) Sample question (German about how to implement jumping to specific statements in the assembler code) that is raised after listening to some parts of the video.

3.3. Digital Materials at the University Level

Since approximately 2005, our university forces and assists lecturers in using new technologies in teaching. What started with some early adopters, was very successful and with 2015 nearly all university teachers now make use of Moodle as an E-Learning platform. Most of them still use it as a repository for their hand-outs only, but quite some apply of all the features that this platform offers.

One lecture, obligatory to several different curricula at the technical faculty of the University of Klagenfurt is called “Introduction to Computing Science”. It is designed for freshmen and takes a closer (and sometimes also deeper) look at the various topics of the field – be it digital numbers, coding, computer architecture, assembler and compiler, networking and so on. The lecture is being constantly optimized, but we found a significant improvement when it came to the examinations (before, dropout was at about 30 % and negative final scores were at about 40 %) after implementing the following changes: (i) we made video tutorials available, (ii) introduced small step-by-step instructions for the most important competencies, and (iii) provided meaningful examples and solutions to the students via the Moodle course. In the accompanying practical labs, we (iv) were supporting the students by introducing group/team work and (v) installed peer tutors. We (vi) provided questionnaires and quizzes and (vii) used animations and simulations to foster their competencies.

It took us a lot of resources to change the lecture, but in the end, it turned out that these efforts were crowned with success. The dropout-rate went back to 10 % and the number of negative scores also went back to 10 %. Even more, the feedback for this class constantly got better. The positive effects on grades was not only due to the use of digital materials, but in terms of feedback, the students appreciated the materials and videos a lot – and thus rate the lecture among the best at our University (it now constantly yields grade 1.0, the median at our Faculty is at 1,70 according to the Austrian grading scheme, where 1 is Very Good and 5 is Not Sufficient).

There was still some room for improvement, and so, in 2018 we decided to make even more use of the digital materials that we have. One challenge in teaching was still the functionality of an assembler (and students lost quite some points at that topic during the examinations). We thus took the video recording of the assembler unit and extended it by making use of H5P, so we added interactivity to the video and added quizzes and explanations to it (see Figure 3). It turned out that the motivation to deal with the content was even higher and the examination results showed that the extra effort again payed off. In the last year (the lecture is read every semester) only one student finished the lecture with a negative grade, and the overall grades also improved. Currently, also a 3D/VR game of a functioning CPU is under development, too, but already now we can say that the use of digital materials payed off. The qualitative feedback that we collected demonstrates that students highly appreciate their use. They mention that they are able to learn whenever and wherever they want, they are motivated to work on the quizzes in teams and, even more, interactivity helped them in preparing for the examinations.

4. Reflection

The previous section briefly presented three examples of the use of digital materials in projects of our department. The use of the

media resulted from the requirements of the teaching scenarios and clearly supports neurodidactic teaching methods. This section summarizes the tackled principles (Discovery, Cooperation, Individuality, and Activity, see Sec. 2.2) and as such, it serves as a guide for teachers seeking arguments for the use of digital media.

Discovery. This type of learning has its basis in pattern recognition, an individual learning rhythm and the modality and multimedia effect. In the elementary and primary school project, digital materials were perfectly suitable as they supported step-by-step instructions and observational learning in form of video tutorials (without reading skills) to deal with very inhomogeneous age-groups resulting in a quite individual learning progress. At the secondary level, we were able to also cover solution-based learning and learning with all senses (3D printing, following a product-chain approach). This is perceived a necessity as the brain always looks for the “whole”, and without the use of digital artefacts, a lot of computing science interventions would lose their connection to reality. Finally, at University level, again digital materials allowed for step-by-step tasks and tutorials for a huge number of students in a course.

Cooperation. This type of learning has its roots in the way how recall and re-storage in long-term memory works, and how information is combined with practical relevance. Digital materials do not seem to be of relevance here, but in the elementary/primary school project they function as glue between the pupils and smaller teams. Recordings are used to communicate and document what happened, and they are shared as a joy to others. Without reading/writing skills this would not have been possible (or only possible with the help of accompanying personnel). At the secondary level, working together on a project in teams or acting as peers is normal. Paper has its limitations (handwriting, changeability, digitalization), and again digital materials act as a catalysator for ideas, they speed up the communication process, allow for quickly modifying design decisions, and finally, allow for sharing ideas (and thus joys) to others immediately. At the university level, digital materials additionally supported team and group work as well as project-based learning, as dislocation of team members could be handled easily.

Individuality. This type of learning has its basis in considering individual interests, needs, tasks, and learning rhythm. It is also influenced by the fact, that new information must be connected to previous knowledge. At age group 4 to 7, digital materials supported self-organized learning to some extent only, as it had to be stimulated by the pedagogues accompanying them. Traditional learning materials can of course also deal with individuality, but the number of physical copies is often limited, they might be occupied by others, and cannot adjust themselves to changing interests. Here, digital materials are helpful insofar, as a lot of recordings/drawings and experiments/task were available for a larger number of pupils at the same time, and the software behind our examples could take care of individual interests. At the secondary and university level questioning and competence-based learning are already supported by common learning management systems, and digital materials in combination with H5P now allow for an even better management of individual interests and a learning rhythm.

Activity. This type of learning is based on the fact that learning is an active process, and that knowledge has to be created by each learner actively. At the elementary and primary level, animations and games helped us to create new stimuli for children and to broaden the set of materials of teachers. At the secondary and University level, a lot of our interventions and units involved creating own digital games (stimulating creative learning) or materials. Especially the holistic approach (design-implement-play) that naturally makes use of digital materials, implies a lot of different activities and thus supports constructionism and constructivism.

The use of digital materials can also be grounded on a neurodidactic basis, or, putting it the other way around: brain-based teaching can be well-supported by digital materials. There are immanent effects (as mentioned in Section 2.1), but there are additional reasons that justify using digital materials in a teaching situation: (i) they allow for dealing with very inhomogeneous learning groups, even without reading/writing skills supporting pattern recognition and an individual learning rhythm, (ii) by following a product-chain model, they can support and stimulate all senses, making use of the modality and multimedia effect, (iii) they extend the possibilities of paper/pencil artefacts by providing the ability to modify and share them instantly and without being on-site, (iv) they are able to “adjust” to the user and thus also can guide the learner through his or her learning experience, (v) they are easy to reproduce and to apply in smaller and larger classroom settings, and finally (vi), they can provide a new and holistic stimuli to the learner, also forcing

them to be more active compared to traditional classroom settings.

5. CONCLUSION

The world's digital transformation will accelerate with the rapid advance of new technologies and this makes investing in digital skills throughout life to be of the utmost importance. Here, digital Materials can be very helpful in this respect as they support the educational process by immanent effects. But, due to missing cause-and-effect relationships the impact of digital learning resources is still rated contradictory.

This paper now takes a closer look at different learning scenarios and projects at the department of informatics didactics at the University of Klagenfurt and relates the use of digital materials to neurodidactic and teaching principles (like discovery-, cooperation-, individuality-, and activity-bases learning). It then shows that there are more than immanent effects contributing to the success and usefulness of digital learning resources, and the presented examples and arguments should help all of us in giving more thought on the use of digital media in our own teaching units in the future.

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The New Functions of OER Repositories for Personalized Learning

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Abstract: ***In digital transformation, the next generation OERs will be more "materials"-oriented and in smaller granularity. They will function in digital ecosystems under the collaboration with other educational information systems and tools. The data transaction and analysis are carried out automatically through IoT (Internet of Things). The roles of human beings will be "consumers as end users" (learners) or "operation mangers" (teachers and mentors). The expected attributes of the metadata will be 1) machine readable (e.g. JSON and JSON-LD), 2) portable (interoperable), 3) secure (data encryption, anonymization, especially in cases that include personal data), 4) efficacious and evident (verification and endorsement, optional), 5) will contain the information of Academic goals and objectives with GUID (Globally Unique Identifier, optional) and 6) will be a subset of next-generation LOM with OER copyright permission elements.***

Index Terms: ***Digital Transformation, International Standards, Learning Object, Metadata, OER, Personalized Learning, Repository, Search***

1. INTRODUCTION: OER

About twenty years ago, under the leadership of Massachusetts Institute of Technology (MIT) and UNESCO, OER (Open Educational Resources) movement was initiated. At UNESCO's 2002 Forum on Open Courseware, OER as a term was introduced and defined as "teaching, learning and research materials in any medium, digital or otherwise, that reside in the public domain or have been released under an open license that permits no-cost access, use, adaptation and redistribution by others with no or limited restrictions. Open licensing is built within the existing framework of intellectual property rights as defined by relevant international conventions and respects the authorship of the work" [1]. After the launching, visionary pioneers realized the social implementations and many stakeholders have found the various roles and niches in the communities. At the 2nd World OER Congress in Ljubljana, Slovenia (2017), it was confirmed that the sustainable development and management, quality assurance, copyright and open license and technical supports using advanced search systems have been the main issues [2]. As the contribution from technologies, while the storage and discovery of the OERs were the priority issue, the new usage of OERs was spotlighted in the context of digital transformation. In the 40th session of the General Conference of UNESCO (12-27 November 2019), the new recommendation on OERs for member countries will be discussed.

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2. OER REPOSITORY AND SEARCH

At the beginning, the number of the OERs was very limited and the users had often difficulties to find the locations. One of the solutions was to store at central repositories or to make the link lists. However, as the number increased rapidly and some managements issues (e.g. the copyright permissions and version managements) appeared, the federated search systems sharing metadata and search results were introduced.

In Japan, while NIER (National Institute for Educational Policy Research) had constructed NICER (National Information Center for Educational Resources) mainly for K-12 Education, NIME (National Institute of Multimedia Education) started educational portal service mainly for higher education. In March 2005, NIME launched a new gateway service on Japanese educational content, called "NIME-glad (Gateway to Learning for Ability Development, [3]). In the same framework, NIME also started "JOCW Search" in October 2006 under the collaboration with the Japan OpenCourseWare Consortium (JOCW). NIME collected the information of OCW content from JOCW member organizations and generated metadata of the content, which were then accumulated in a metadata repository called a 'referatory'. Both NICER and NIME aggregated the metadata based on LOM (Learning Object Metadata [4]). They exchanged each other periodically for users' conveniences. In NIME's mid-term plan of FY2004-2008, a national infrastructure for the sharing and distribution of digital learning resources was one of the strategic goals. While NIME had already begun several services before [5][6][7], NIME integrated them into the new "NIME-glad" system (Figure 1, at the

end of this article, shown in NIME Handbook by Yasutaka Shimizu).

2.1 International Collaborative Framework: GLOBE as a Federation of Metadata Repositories

As a result, numerous OERs had been accumulated in repositories worldwide, some common platforms and strategies for collecting information and content are indispensable in order to find and retrieve quality content efficiently from scattered and distributed sources.

In order to facilitate the international sharing and exchange of high-quality learning content, the core organization in each country and region, which managed the functions for federated repositories and meta-referatory, established the "Global Learning Objects Brokered Exchange (GLOBE)" consortium in September 2004. The original members were ARIADNE (EU), education.au limited (Australia), eduSource Canada (Canada, [8]), MERLOT (North America), and the National Institute of Multimedia Education (NIME, Japan) [9]. Currently, the number of GLOBE members is 14; eduSource Canada was replaced with LORNET in February 2006, NIME was merged into the Open University of Japan as Center of ICT and Distance Education (OUJ-CODE) in April 2009 and education.au limited was merged into Education Services Australia in March 2010. Korea Educational Research and Information Services (KERIS, Korea), European Schoolnet (EU), the Center for Open Sustainable Learning, Utah State University (COSL, USA), and Latin-American Community of Learning Objects (LACLO, Latin America) joined GLOBE in 2007, Institute for Information Industry (III, Taiwan) and Institute for the Study of Knowledge Management in Education (ISKME, USA) in 2008, Thailand Cyber University Project under the Higher Education Commission (TCU, Thailand) in 2009, Inter-University Center for e-Learning (MEITAL, Israel), Eummena Organization and Al-Quds University (Arabic countries), and OER Africa (African countries) in 2010. One of the GLOBE's objectives is to assure the quality of the cross-institutional searches by sharing the metadata, which GLOBE members have collected. ([10]). Several GLOBE members are also members of OCWC and/or have deep commitments to other OER movements.

2.2 Technologies for Cross-Institutional Search

In order to realize a cross-institutional search, the participating institutions should share both the technical standards on the description and communication and the policy for sharing content and metadata.

"Federated search" is one of the cross-database search methodologies without sharing the full set of or a part of the metadata among database(s). For example, at the establishment in 2004, GLOBE member organizations could not share the full metadata set with others because they were not always the copyright holder of the metadata. GLOBE adopted a federated search architecture and connected in "one-to-one correspondence" fashion using Simple Query Interface (SQI, cf. [11]) as the query language.

"Metadata harvesting" is a means of collecting metadata from multiple repositories and the Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH, cf. [12], 2002) provided an

Table 1 Metadata elements used in "JOCW Search"

No.	*Metadata elements*	*Corresponding element to IEEE 1484.12.1-2002*
1.	ID of the metadata	3.1 Meta-Metadata - Identifier
2.	ID of the LO[1]	*1.1 General - Identifier*
3.	Title	*1.2 General - Title*
4.	Language(s) used within the LO	*1.3 General - Language*
5.	Description	*1.4 General - Description*
6.	Keyword(s)	*1.5 General - Keyword*
7.	Aggregation level	1.8 General - Aggregation Level
8.	Contributor to the LO	*2.3 Life Cycle - Contribute*
9.	Language of the metadata	3.4 Meta-Metadata - Language
10.	MIME media types of the LO	4.1 Technical - Format
11.	URL	*4.3 Technical - Location*
12.	Technical requirements to use the LO	4.4 Technical - Requirement
13.	Educational stages[2]	*5.6 Educational - Context*
14.	Intended learning time	5.9 Educational - Typical Learning Time
15.	Intended user of the LO	5.10 Educational - Description
16.	Paid-for or free	*6.1 Rights - Cost*
17.	Restriction of usage	*6.3 Rights - Description*
18.	Classification[3]	9. Classification
19.	Copyright[4]	-
20.	Quality[5]	-
21.	Permission to Harvesting	- (for GLOBE Harvesting)
22.	Permission to Federated Search	- (for GLOBE Federated search)

LO: Learning Object, Gray-colored cells show GLOBE Mandatory fields; *Italic* cells show GLOBE Recommended fields.
Note: 1) ID of the LO is generated automatically as Catalog is "URL". Entry is the actual URL. 2) Educational stages have unique value space matched to Japanese educational system. 3) Classification shows the taxonomy system and its value(s). 4) Copyright shows the right management system and its value(s). 5) Quality shows the quality assurance system and its value(s).

application-independent interoperability.

The globally accepted metadata standards in educational field were IEEE LOM (Learning Object Metadata, cf. [4]) and Dublin Core (DC, cf. http://dublincore.org/). The metadata standard of GLOBE was Learning Object Metadata (LOM) version 1.0 (Table 1).

With the dissemination of OER concept, it was considered that the metadata of both open and proprietary content should be free and open to the public. As a result, metadata harvesting spread for the sharing and reuse.

2.3 Limitation of GLOBE and Advent of xMOOCs

After the advent of xMOOCs in 2012 (in North America; in 2013 in Japan), the presence of OER repositories were unobtrusive temporarily and the purposes and roles were reexamined.

In Japan, after the abolishment of NIME, the metadata of OERs at universities were managed at each institutional repository and are shared through JAIRO Cloud which were operated by National Institute of Informatics (NII) [13]. The issues at that time were 1) the cost of tagging metadata and 2) difficulties of the new value-added services utilizing a variety of metadata information. The balance between the cost and the quality of information was not maintained in sustainable way. In 2013, while the author started a new repository project focusing on materials-oriented content mainly for teachers and course developers (called "Materials repository", [14][15]), it was not realized in the community because technologies had not matured sufficiently for it. Thereafter, GLOBE entered a long silent period until today (Table 2).

3. OERs in Digital Transformation

In recent years, the governments in the world announced the new framework of industries (e.g. "Industries 4.0" in Germany, "Made in China 2025") and societies (e.g. "Society 5.0" in Japan). "Society 5.0" (Japanese Cabinet Office, [16]) showed not only the future of industries and factories but that of human societies. In Society 5.0, the roles of ICTs (Information and Communication Technologies) are expected to change from the methods of digitization to the drivers of digital transformation (DX).

In "Society 4.0", the relationship of granularity of the learning content and reusability was as follows:

- "Top-down" usage: The copyright holder opens the content in large-granular size, such as courseware and textbooks, with the permission to break down the parts ("materials) and reuse.
- "Bottom-up" usage: The copyright holder opens the content in small-granular size, such as images, short concept movies, tables and figures, simulation and so on. Generally, learners as end-users use the content as a finished product without reedit by themselves ("Top-down" usage). Teachers and course providers need small-granular materials in order to appeal the originality even if the parts and materials belong to others.

Learning environments and processes will change drastically. EDUCAUSE and IMS Global Learning Consortium launched Next Generation Digital Learning Environments (NGDLE) in 2014 [17][18]. Five characteristics of NGDLE were; The fair and personalized (i.e. individually optimized) learning process was included as a goal. Each courseware as a phenotype of the standard curriculum will be specific and original in each personal context, while each component and module of the courseware should be sharable for the sustainable development. In addition to

Table 2 Expected evolution of OER repository

Service name	Expected Main users	Purposes/Granularity	Number of learning objects/ Metadata generation	Distinctive Metadata items
Initial OER repository (NIME glad, GLOBE)	Learners	To find courseware and textbooks	Limited/ manual possible	Goals, Evidences,
"Materials" repository [14][15]	Teachers, Course providers	To find materials of developing courses or books	Many/ semi-automatic	Copyright Permission
Next Generation OER repositories	Machine (AI)	To find and retrieve the right module/ component (LO) in each personal process	Many/ full-automatic	Machine-readable description, Objectives and Goals with GUID (cf. CASE, Learning Pathway, IMS Global),

* CASE (Competency and Academic Standards Exchange) and Learning Pathway are the technical standards of IMS Global Learning Consortium.

other in more interoperable ways and exchange and share data in more standardized fashions. Innovative tools and services which utilize such imported and linked data will induce new stakeholders and value-added activities.

When conventional online course (that is, SPOC) providers or MOOC providers construct a fair and personalized (individually optimized) learning process in sustainable fashion, digital ecosystem of tools and content materials is indispensable. The prerequisite of the digital ecosystem is interoperability, and IMS technical standard is a set of the agreements for interoperability among stakeholders in educational fields.

In these five years, IMS technical standards were drastically changed ([19]) and they got potentials to realize a fair and personalized (individually optimized) learning process. With developing of the optimization algorithm, the standardizations of both learner record and learning pathway are also discussed.

4. Requirements in Next Generation OER Metadata

If online courses, whether open or private, change to be personalized, the content to be shared will be "materials"-oriented. Comparing with finished and fixed courseware or textbooks, the number of contents will become bigger and some *automatic generation* is inevitable. If each learning process should be optimized, it is necessary to identify the goal of the learning process and the context (location at the curriculum or learner's personal history) in more minute fashion. Considering cross-institutional and cross-border distribution, it is preferable to describe issues in some standard curriculum and personal record (*fine structure*). As the evidences on the effects will be experiential, some data collecting and storing mechanism is also necessary for the quality assurance of metadata. Although it is a content management system (CMS), the records of the usage should be also necessary. At Initial OER repositories, it was examined that human users can tag (social tagging) and it was known as folksonomy approach. In DX, CMS may automatically retrieve the evidences on outcomes from log-data at LMS and LRS. The blockchain technologies to store the learner record in distributed fashions is another option to utilize personal data under data subject's control.

To sum up, expected attributes of next generation OER metadata are as follows:

1. Machine readable (e.g. JSON and JSON-LD)
2. Portability (i.e. Interoperability)
3. Security (data encryption, anonymization, especially in cases which include personal data)
4. Academic goals and objectives with GUID (optional)
5. Efficacy and the evidence (verification and endorsement, optional)
6. Subset of next-generation LOM with OER copyright permission elements

5. Conclusion; Next Generation OER Repositories

In the midst of Digital Transformation (DX), OER repositories will also evolve. One of the purposes of Next Generation Digital Learning Environment (NGDLE) and the followers (that is, N2GDLE, "Next Next Generation Digital Learning Environment", [20]) is "personalized learning". What is shared is materials, that is, modules and components of courseware and e-books as original meaning of Learning Objects. OERs will be managed in smaller granular level and the main users will be not only human learners and teachers but, also, AI (Artificial Intelligence), that is, machines. Next Generation OER repository will be one of the tools in digital ecosystem, in which tools exchange data in a standardized fashion (e.g. RESTful API). In order to find and retrieve the right content in each environment and context, the next generation metadata in OER repositories will include the metadata elements on academic information using GUID in addition to conventional keywords. Also, OER repositories will have functions to store records of usages and outcomes. The records will be sorted by content in LRS or collected from learning platforms directly. As the records include some personal data, when sending them back to CMS (OER repositories), anonymization is indispensable under the regulations in each country and region (such as FERPA (Family Educational Rights and Privacy Act) in USA and GDPR (General Data Protection Regulation, enacted in 25 May 2018) in EU).

The elements of data transaction are as follows:

1. Use identification
2. Sending query
3. Return search results (list or material)
4. Return outcome results or issue a badge
5. Reflect the outcomes into the metadata database

While IMS technical standards are effective to realize these transactions, it is still necessary to develop or revise standards.

The next generation OERs will be more "materials"-oriented and in smaller granularity. They will function in digital ecosystems under the collaboration with other educational information systems and tools. Data transactions and analysis will be carried out automatically through IoT

(Internet of Things). The roles of human beings will be “consumers as end users” (learners) or “operation mangers” (teachers and mentors). In 10 years break of GLOBE, technologies and standardization have progressed. Toward personalized learning as a final goal, the restructuring the metadata standard (LOM 2.0) and international collaboration of repositories (GLOBE 2.0) is expected.

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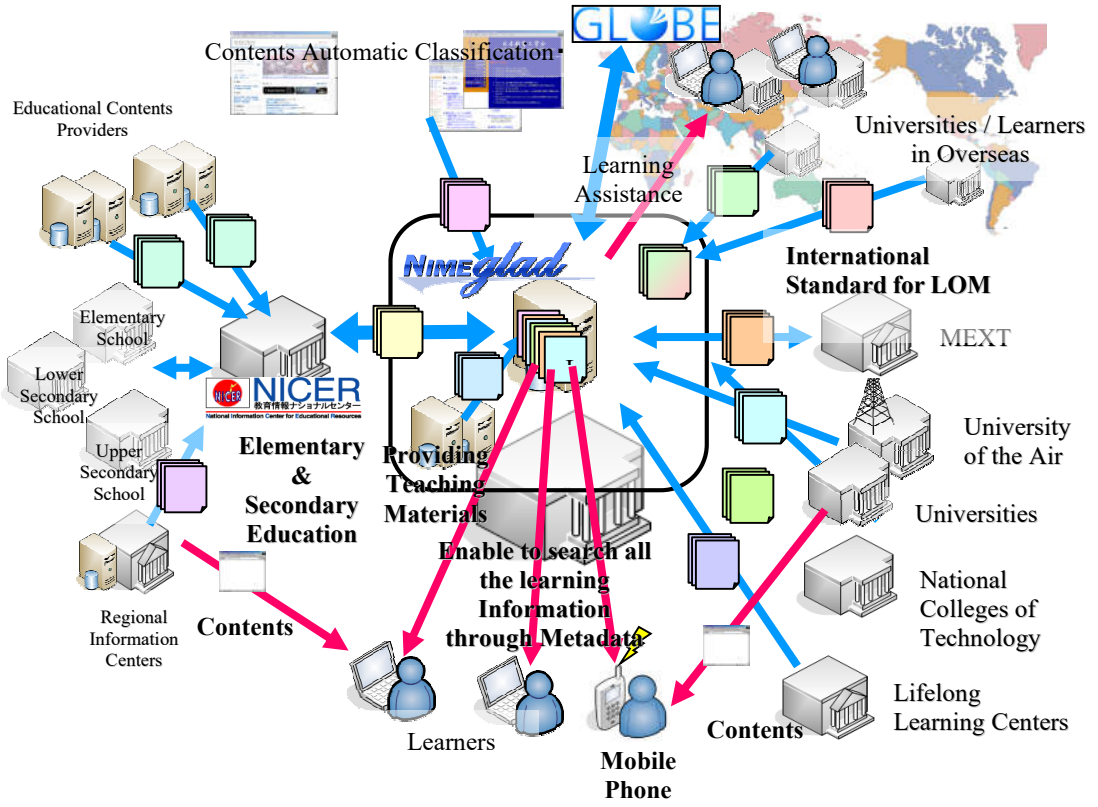

Figure 1 The concept of “NIME-glad (Gateway to Learning for Ability Development)” (from NIME handbook, by Shimizu, Y.)

Preserving Cultural Knowledge through Community-Led MOOCs

Kulathuramaiyer, Narayanan; Pariyar, Amit; Bala, Poline;
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Abstract: ***MOOCs have cultured a knowledge exchange phenomenon at a global scale making its strong presence in developing countries to pursue certain development goals, particularly to serve the rural indigenous communities. The current MOOC model, however tends to be inhibitive when it comes to integrating the complex realities of the under-served communities and their way of life. The growing commercial interests, increasing corporate partnerships, the 'outside in' course focus, one-way knowledge transfer, threats to local knowledge and decontextualized innovation are some aspects that questions its relevance to serve a social purpose. This paper aggregates the inadequacies of the current linear model of MOOC with a function model and exemplifies our 'Community-Led MOOCs' as a model to preserve cultural knowledge. The novel case of preserving the knowledge on threading and stringing Kelabit beads provides a compelling evidence that intergenerational knowledge sharing can be reestablished by giving the community the center stage in producing MOOCs and connecting the youths to the elderly population.***

Index Terms: ***Bario, Community-Led MOOCs, Culture Preservation, Indigenous knowledge Kelabit Beads***

1. INTRODUCTION

THE emerging knowledge society is empowering each and every one with the capability to contribute to the digital knowledge repositories of this vast universe. This has then cultured a knowledge exchange phenomenon at a global scale. The Massive Open Online Course (MOOC) is a manifestation of this phenomena which started in 2007 with developments such as Khan Academy, Coursera, Udacity and edX. Despite the promise and excitement surrounding the use of MOOCs, we will see why the currently prevalent MOOC model tends to be inhibitive.

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This research then promotes the concept of 'Community-Led MOOCs' as an alternative model of MOOCs (Pariyar et. al, 2020) which does not exploit or marginalize under-served communities. Extending the radical initiative to put a community in the driver seat of a MOOC, this paper elucidates its potential of preserving cultural knowledge. In this respect, the proposed MOOC model serves as a platform for Knowledge Management, where the outcome of learning will then populate a digital repository of local content, with contents created in the context of empowering a learning community.

The key developments relating to MOOCs will be discussed in section 2, where we address the challenges faced by current MOOCs, particularly in its repurposing to serve a societal problem. The concerns on the current delimiting use of MOOCs will also be highlighted. Section 3 then describes the pioneering work undertaken at the Institute of Social Informatics and Technological Innovations (ISITI), Universiti Malaysia Sarawak (UNIMAS), in turning MOOCs into a tool to support a social cause which is the preservation of culture. Section 4 then describes how we designed the learning contents that has adapted and restructured a MOOCs capacity to serve as a knowledge creation platform. Section 5 subsequently discusses the pilot MOOC specifically designed for a purpose describing the outcomes of focus group discussions and the preliminary workshops carried out in remote and rural sites throughout the Bornean Malaysian state of Sarawak.

2. CAN MOOCS ACTUALLY SERVE A SOCIAL PURPOSE?

MOOCs is hauled by many as a viable solution to develop education in the global south. For instance, the leader of mainstream MOOC provider, Anant Agrawal (2014) from edX, is optimistic that MOOCs will democratize education, especially higher education, by making it accessible to everyone. The increasing growth in mobile penetration and internet connectivity in developing countries from 7.7 per cent in 2005 to 45.3 per cent at the end of 2018 (ITU, 2018) is also a compelling statistic for

development practitioners to regard MOOCs as a promising technology to pursue certain development goals to benefit developing countries. This has strategized MOOCs development, especially the dominant xMOOCs (Panyajamorn et. al, 2016; Warugaba et. al, 2016; King et. al, 2018), to address the learning needs of communities in developing countries belonging to various diaspora, including the rural indigenous communities. There is however a need to take a step back to reassess the current model to see if it blends in with the complex realities of the under-served communities and whether it is supportive of their learning context and way of life.

2.1 Commercial Interest

The MOOCs gained popularity in the developing countries during its infancy for two primary reasons. The opportunity to enroll in courses offered by the best universities in the world, and having to pay nothing to gain access to the learning materials. The trends in current MOOC development show that the original philosophy of MOOCs is deviating on various grounds. The commercially slanted MOOCs model can be seen as partly deviating from its notion of openness to pursue a revenue generation business model through certification and specialized programs. This creates a suboptimal experience for southern learners (Kalman, 2014).

2.2 Corporate Partnership

The increasing partnerships of MOOC providers such as Udacity and Coursera with corporate institutions also indicates the shift from being 'learner focused' to one that serves the best interests of the partnering institutions. The tendency of commercial MOOC platforms to copyright-protect their learning materials, also means that developing countries will lose the freedom to adapt, localize or translate content to their own context (Boga et. al, 2014). From a community perspective, MOOCs pedagogical design is being replicated at all levels to ensure inclusive learning, which on the contrary is creating exclusion for rural communities.

2.3 Outside in Focus

The 'outside-in' course knowledge-flow is evident. For instance, MOOCs from established universities are being integrated into the curriculum of developing countries. This, on the one hand, raises question on the status quo of education system in the global south and on the other hand creates a situation for learners to readily accept the knowledge that is being served to them, in a view to compete with global learners. The latter is an alarming situation and this is where the skewed MOOC model needs to re-examined (Pariyar et. al, 2020). (Altbach, 2014) critiques the western dominance of education on the global south while (Adam, 2013) stresses on a situation for learners to either take it or leave it. The local communities are further challenged in their role as a contributor in the knowledge exchange.

2.4 One Way Knowledge Flow

The knowledge flow supported by MOOCs is predominantly one-way as the learner's engagement continues to revolve solely around the subject materials and activities planned by the instructor. This means that the learning outcome is fully dependent on individual initiative. By focusing on individual learning pursuit, MOOCs, in a way, have undermined the value of togetherness that the community seeks in accomplishing their learning goals. With these developments in MOOCs, the assumption that MOOCs can be replicated to deliver inclusive learning experience for rural communities is turning out to be impractical.

2.5 One Size Fits All

Also, for MOOCs to serve as a developmental vehicle, a one-size-fits-all model cannot be adopted. The traditional linear Information and Communication Technology for Development (ICT4D) model advocating a one-way flow of knowledge has been shown to be inadequate for the purpose (Bon, 2019).

2.6 Threats to Local Knowledge

In existing MOOCs, learning materials that constitute the MOOC modules are pre-recorded and structured around weekly activities, carrying a unidirectional message guided from a centralized source. In replicating the model of MOOC for developing countries, the one-way knowledge flow from the global north to the south is being propagated. This however puts the local, cultural knowledge in a threatened position as with the increasing pressures sensed by the rural indigenous communities to adapt to the global knowledge. The danger lies in the replication of global knowledge which undervalues the local knowledge and pushes the community to adopt new knowledge at the expense of losing their own traditional culture, customs and knowledge.

2.7 Complex Realities of Local Context

Community's lifestyle has evolved in the backdrop of poverty and hardships. Their outlook is experiential, intergenerational and locally driven which is the reason why they care so

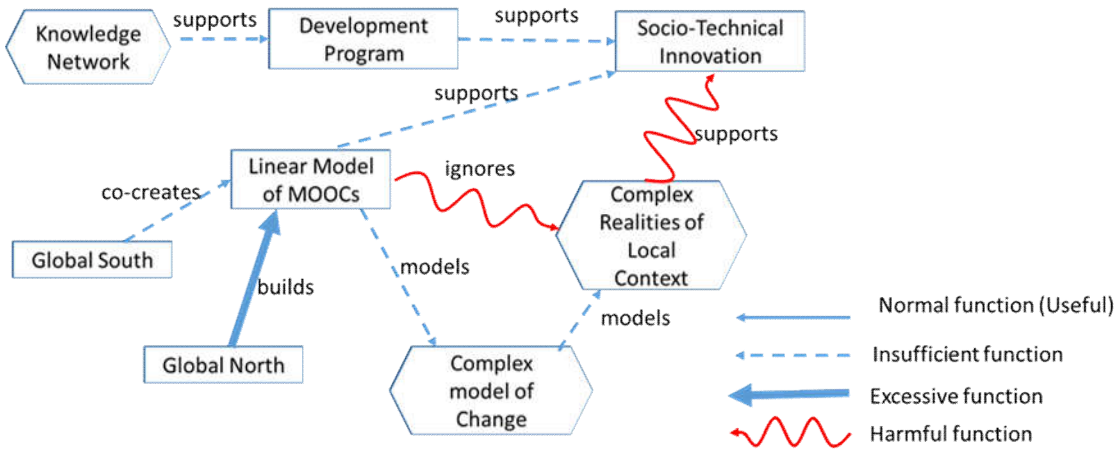

Figure 1: Function Model illustrating a typical MOOC model

much for their social, cultural and ecological resources. Their priorities are need-based. For instance, for farmers harvesting their crops is more important that attending a MOOC course. In many cases, communities are also not supportive of the development agendas when it does not align with their core values of unity and produces collective benefits to all members of the community. The incident of objection shown by the Penan community to the road construction project despite being of economic value, affirms the sensitivity of community towards their 'way of life' (Borneo Post, 2013). The Penan communities feared that the economic benefits would be disproportionately shared among members of the community (Pariyar et. al, 2019).

Technology, such as the current MOOCs, has to be customized to serve localized learning needs. This however, cannot overlook the complex realities of local contexts [Bon, 2018]. Each local community has to be tailor-made and modelled in a way that the actual learning needs are addressed in context. We will present via a case study (see section 4) how the complex realities can be intricately blended together to direct and support learning activities. In modelling the complex realities of local underserved communities (see Figure 1), socio-technical innovation is realized through the close assimilation of technology in a social context. The social context then links the community's day-to-day activities with the need to learn and subsequently work collectively towards cultural preservation activities.

2.8 Decontextualized Innovation

Innovation is often treated a black-box and at times is driven solely by technological possibilities. Innovative applications cannot be seen as being isolated or de-contextualized from their environmental surroundings; that is to say, such applications are accepted by users and society at large when they fit within the regulatory frameworks of the economic and social factors (Maclaine et. al, 2016). The MOOCs, as a socio-technical system, have the potential to deliver value for rural communities. However, in order to enrich social impact, an intricate modelling of interactions between technological and social aspects is needed. The capability to capture the networked relationship in local learning loops of rural communities needs to therefore blend in with the way of life of the community.

The inadequacies in the current MOOC development as highlighted in this section positions MOOCs as an alternative linear model to serve the social purpose. Adopting such a linear model of MOOCs to pursue developmental goals for grass root communities influences knowledge creation and sharing capabilities among the participants, particularly the marginalized communities at the fringe of mainstream development. The development programmes that were intended to produce socio-technical innovations become marginalized (see Figure 1) due to lack support in the knowledge exchange process. The inadequacies of a linear MOOC model (as adopted in current MOOCs) has been aggregated and modelled as a functional model based on (Bon, 2019; Kulathuramaiyer, 2019).

The problem is further described in Figure 2. Underserved populations are subjected to a technology-bias through the one-way knowledge flow. This leads to severe level of indoctrination resulting in the total inability to foster creativity and to effectively contribute ideas. Traditional MOOCs therefore restrict innovation and lead to

inability to respond through balanced development programmes.

to become a people-centered platform requires a change in perspective. The user cannot be treated as a passive recipient of de-contextualized knowledge. Figure 3 shows a

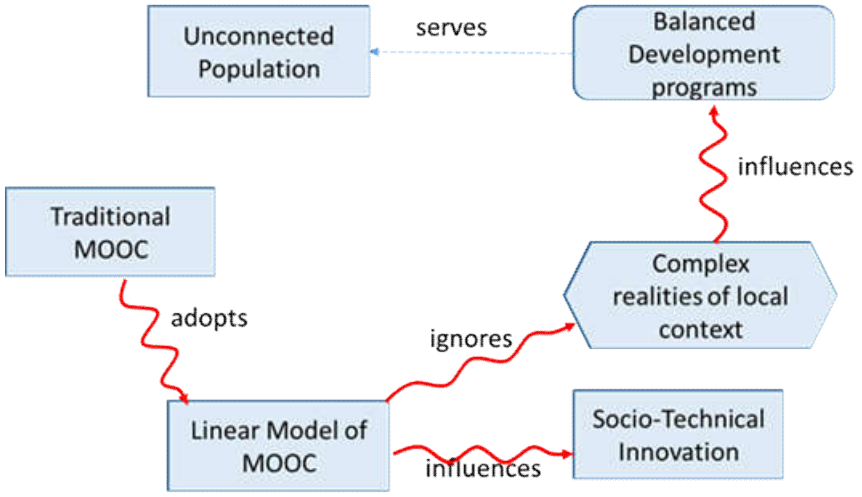

Figure 2: Function Model describing the challenges of linear Model of MOOC

3. *MOOC Model for Culture Preservation*

The characteristic feature of MOOCs that makes it immensely useful as a knowledge management platform is its ability to capture knowledge from the ground described in (Pariyar et. al, 2020) and make it accessible to larger audiences. This allows MOOCs to be applicable to countless use cases to meet certain specific objectives. This paper will focus on the area of culture preservation, an agenda that is of primary concern as the importance of local indigenous knowledge is being acknowledged in the face of global crisis.

There is undoubtedly a global concern raised over the depleting local, indigenous and cultural knowledge resources. Specifically, in the areas of cultural heritage; the intangible resources such as the music, dance, arts, and craftsmanship, which symbolize a unique 'way of life' of a community, is at an extremely vulnerable position (UNESCO, 2018; ScienceDaily,2019). The modernization and urbanization often appear as a general reason but at the crux of this problem is the inability to document the knowledge resources. The most basic but crucial activity such as communication between youth and elders within a community is overlooked in the 'technology driven initiatives' which do not produce desirable outcomes. MOOCs has the potential to revive the traditional knowledge sharing process, passing knowledge from older generation to youths, which is most familiar to the local indigenous communities.

However, the effort in transforming the traditional one-way technology such as MOOCs typical MOOC design, that stems from the emphasis on technology rather than people. This directs MOOCs development as a linear model to serve a social purpose in which community members have a marginalized role in knowledge sharing.

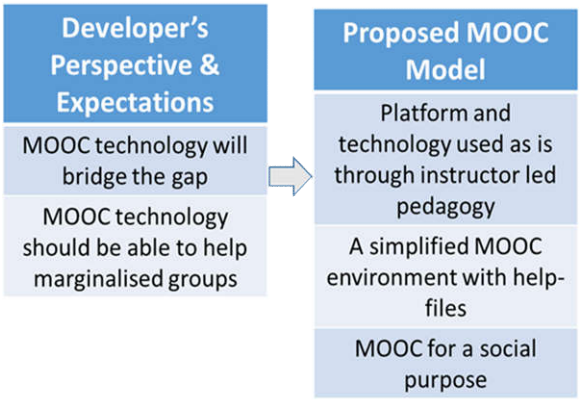

Figure 3: Traditional MOOC design

Figure 4 : MOOC for Culture Preservation

complex model of change by becoming the culture preservation platform. The details will be discussed via a case study in the next section. The pilot MOOC that has been developed has demonstrated the potential to serve as a social platform to empower unconnected populations.

4. *Community-Led MOOCs: Case Study in Bario*

The introduction of MOOCs to the Kelabit community is a recent initiative by ISITI to explore the delivery of inclusive learning in a remote, rural setting by their own local champions. This effort is seen as an expansion of promoting creative expressions as a means of harnessing indigenous knowledge over the past 12 years (Zaman, et, al., 2013; Zaman, et, al.,

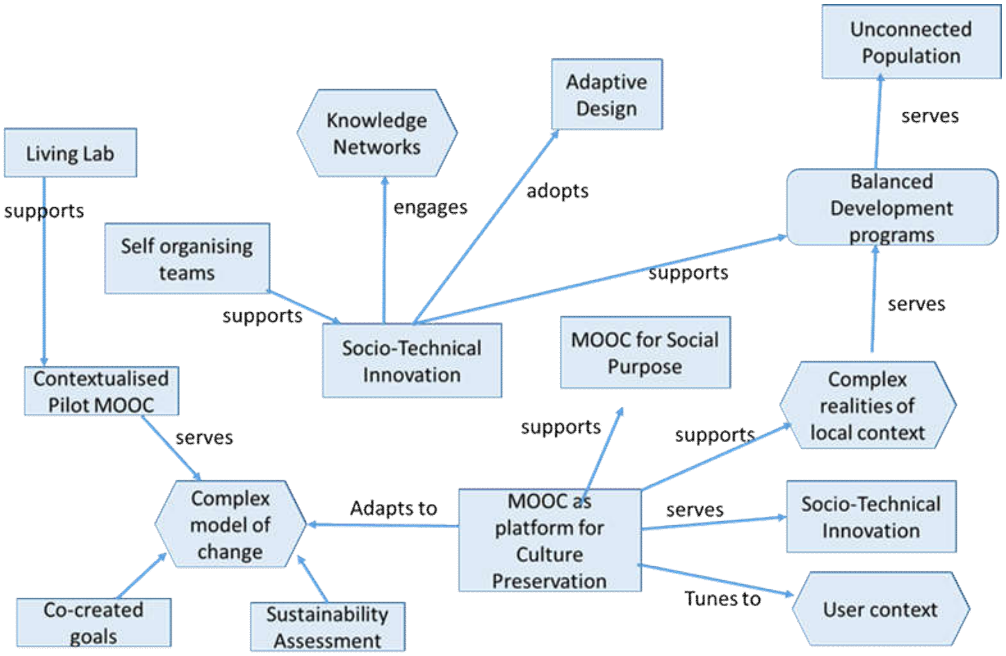

Figure 5: MOOC design that considered complex realities of Context

Figure 4 illustrates the change in role of the MOOC platform to allow users to create their own learning modules and become recognized for contributing knowledge, thoughts and ideas. This directs MOOC development for a social purpose with a 'community-led model' in which role of community members is shifted from passive contributor to equal partners in knowledge sharing and the outcome is derived from the collective efforts of the community in a bottom up fashion.

As shown in Figure 5, this transformation is demonstrated via the embedding of a pilot MOOC course that was developed together through a partnership with rural, indigenous communities. The MOOC model served as the

2014). Bario was identified as a site for the MOOCs project based on the close collaborative relationship shared between the community and the institute, and also the keen interest shown by the community towards the project. Initial focus group interviews were conducted with the community members, introducing them to the project as well as to find out what their opinions and thoughts were with regards to the proposed MOOCs programme. During the discussion held with the community members, it was explained to them that the MOOCs platform would be a means for them to store and share their knowledge, expertise, experience, and skills with others.

This was one of the areas that the community members were eager to participate in, as they were interested in knowledge preservation. The interviews conducted with the community members revealed that they were very keen on the idea of MOOCs as a basis of sharing their traditional knowledge, as they were interested in looking for ways to preserve their local knowledge for the benefit of the younger generation. A community elder stated that:

"Learning is important for the community, and we need to make every moment count to ensure that we pass on our knowledge to the future generations. The power of the Internet could be harnessed for this purpose, and holds the key towards the dissemination of our indigenous knowledge"

Other responses from the community members include:

"This programme (MOOCs) seems like a good programme. We have a lot of knowledge in our heads, but we don't know how to pass it on to others. Nowadays, our children and grandchildren do not spend as much time with us as we did with our elders. They are interested in using devices, so maybe this is a good way to share our knowledge."

"Using videos to record our knowledge is a good way to keep what we know for a long time. We can tell them our stories through our own voices, and pass down what we know to our future generations."

The focus-group sessions allowed the community to relate to the concept of the MOOC to their daily lives. The community members tend to be vocal about what they wanted to present in the MOOCs and were very keen to be involved in developing the content of the MOOCs.

"We are interested in learning more about how to look after our health, and what types of local herbs or plants can be used as medicines. As we grow older, there are many things that we have to take care of, and our health is important to us. If we can learn from other indigenous communities about how they make use of medicinal herbs, we can use that knowledge not only for ourselves, but for our younger generations as well."

Apart from that, potential community champion candidates were identified and asked if they could take on the roles of mentors and facilitators for the MOOCs. This participatory approach of involving the community members as the leaders of the MOOCs is especially important for this project, as this would ensure that the community members felt ownership over the content of the programme, and see value in participating in the MOOCs. The role reversal from learner to instructor also provided the community members with a platform to share their knowledge and expertise with their audiences, allowing them to recognize their potential of becoming esteemed contributors of knowledge.

"I want to teach my grandchildren how to make this ornament using beads. There are many techniques that they should know, and they can only learn from us. Nobody else knows how to do this; they cannot learn it on their own. They have to learn from us."

Despite having limited knowledge of ICTs, the community members were keen on learning how to make short videos using their mobile devices. A few community members were also identified to take on the role of documenting the process, and several videos were taken of the community elders explaining the topic, before teaching them how to produce local content. This way of teaching and learning through observation is also one of the ways that the Kelabit community learns. An elder remarked:

"We teach our younger generation by showing them how it is done. They learn from observing and trying it out for themselves. We don't teach them by giving them instructions, because for us, when they try and do it for themselves after seeing us doing it, that knowledge will last longer in their minds."

A few community members were also identified to take on the role of documenting the process, and uploading the content onto a shared space which could be accessed by the team at UNIMAS, easing the task of content sharing. They were more than eager to share their traditional knowledge with the youngsters rather than to use this medium to learn new skills and expertise.

The community-led MOOCs pedagogical design required communities in Bario to undertake interchangeable roles as community scholar, facilitator, and learner. The facilitators helped document the local knowledge while the community scholars, primarily single mothers, shared their skills, stories and history associated with the beads. The learners represented the youths, tourists and other residents. The unique aspect of this pedagogy is that it represented community as equal learning partners, reflected their core values and responded to their lifestyle situations.

4.1 Preserving the Cultural Knowledge on Threading Beads

ISITI with the COMPETEN-SEA project (http://competen-sea.eu/) funded by the European Commission to develop educational services targeted to various unprivileged groups, envisioned an educational programme intervention in Bario that would allow a group of single mothers to document their knowledge and skills on threading and stringing of Kelabit beads via 'Community Led MOOCs'. An extension of the traditional 'instructor led pedagogy', was seen to be not suited for the purpose. Instead, a model that supported bottom up, inclusive and participatory learning was needed.

Figure. 8. Community scholars sharing their knowledge on beads

Figure. 6. Behind the Scene: Recording Session

Figure 7: Briefing session between facilitator and community scholars

Through community led MOOCs, the local communities are pushed to the forefront in building local knowledge repositories by integrating three elements in the pedagogical design: community participation, their learning context and way of life (Pariyar et. al, 2019). Enhancing basic skills such as taking photo and recording videos, was firstly incorporated to facilitate the local community's participation in technology-based learning activities leading to cultural knowledge preservation. The community members served the three interchangeable roles: facilitators, community scholars, and learners. Figure 6 depicts the behind the scene of MOOCs production in which a facilitator is seen recording the knowledge shared by the community scholars. The facilitators engaged in a briefing session (Figure 7) to help document the local knowledge while the community scholars (Figure 8) mostly elderly members shared their skills, stories, and histories associated with the beads.

The project was then focused on preserving the traditional knowledge closed to the hearts of the community. In Bario, the area "preserving the knowledge threading beads" was selected. The beads hold cultural significance and are special to the Kelabit communities in Bario. They are regarded as objects of desire, indicated wealth – family heirloom, power, and carry coded message of beauty (Bala, 2019). Figure 9 shows some the artifacts such as necklaces, hats, and bracelets made of the beads. There is a growing need expressed by the community of single mothers to preserve the history, knowledge and skills, and the stories associated with the beads. Shrinking population of the elderly generations and the migration of youths, reduced the chances to pass on the skills and knowledge to the future generations. This prompted social innovation endeavors with MOOCs to serve the cultural knowledge preservation needs and to bridge the knowledge gap with the younger Kelabit population, and the rest of the world.

5. DESIGN CONSIDERATIONS FOR THE PILOT MOOC

The MOOC system was developed using OpenEdX platform with modules comprising of a

mix of external 'expert designed' modules in the area of Honey Harvesting, Cake Making, and Composting; 'community-led' modules which includes Traditional Food Production, and Bead-Threading; 'learner-contributed' modules under the heading of Knowledge Preservation; and a Community Scholar Registration and Certification module (see Figure 10). A key feature of the MOOC platform is in allowing the recognition of facilitators of MOOCs for their diverse range of contributions.

The project has moved to a phase where we have concluded a feasibility study to run the MOOC course in a Pusat Internet (Internet Centre) in areas around Kuching and Kota Samarahan, remote communities in Bario and Bakelalan and the state library's facilities in Miri. Although the content creation session made use of the MOOC platform as a learning platform, the current phase of interaction has been mainly via face-to-face workshops and focus group discussions. The face-to-face version of the MOOCs was required to be augmented by WhatsApp-based interactions with Community-leads and facilitators as well as Trello-based collaborative boards as a medium of populating learners and community scholar profiles.

We have managed to address the challenges that have the potential to inhibit learning in under-served communities which include physical, social, and psychological factors. The infrastructure limitation and digital incompetency have been addressed through the training of community leads and the close work between instructors and community members.

Though community led MOOCs sparked interest among community members to enrich local learning and promote Kelabit culture to outsiders, some challenges also came to light during the field visit. The connectivity in Bario was unstable which means that the activities related to uploading contents to online platforms such as edX is still an issue. There is a need to introduce an offline learning platform with support for content synchronization to online servers whenever online connection is available. The pre-requisites such an email account to register as learners in online learning platforms and the need for mobile numbers to register for email account also complicates basic tasks. This is because most of the community members do not have email account and some of them do not prefer to share their contact numbers. There is a need to

Figure. 9. Artefacts made from Kelabit Beads

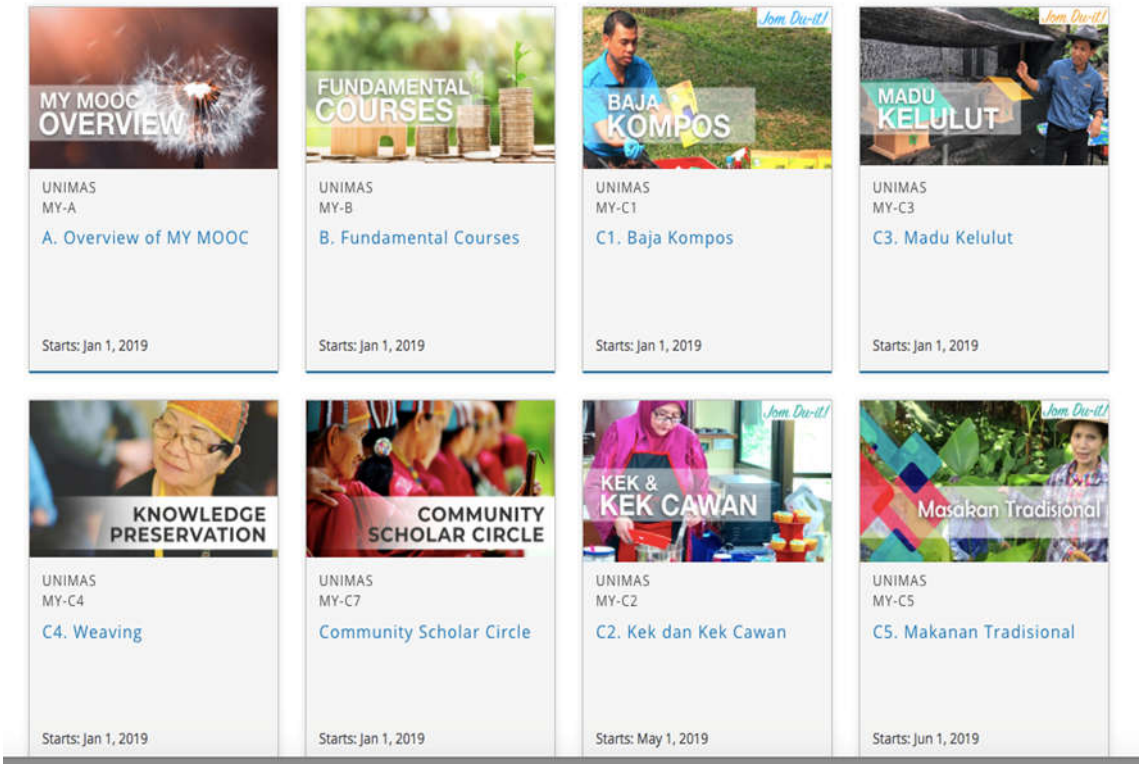

Figure. 10. Snapshot of Pilot MOOCs

generate proxy email accounts so that some community members such as youths can be assigned as intermediaries who can share the knowledge gained from accessing contents to the secondary learners. Support tool such as Trello was also found useful which would allow facilitators to store community profiles, record log of activities and upload contents temporarily prior to uploading them to online learning platforms.

6. LESSONS LEARNED

The community has benefited from the social learning experience with the support of the local network of learners and support groups. This has enabled a local learning loop that will continue the learning to happen beyond what MOOCs can provide. The local learning loop augments the learners by addressing the knowledge gaps for them to work with global MOOC communities. The global practices and theories need to be brought in to broaden the community's worldview in a way that supports the expansion of local knowledge and enrichment of local culture. The continued interest in learning can only be guaranteed when community perceives learning as contributing to the preservation of their local culture and knowledge for their future generations.

MOOCs has to be delivered in a way that it does not impose time commitments and other financial insecurities. Learning scenarios have been designed around the informal gatherings which the communities are more used to as they live in close proximity with each other. The role of MOOCs should highlight the 'quality of life' and the ability of communities to preserve their social, cultural and ecological resources. The community should be able to document and record their lifestyles and build a repertoire of local knowledge which can be passed to future generations.

The community-led MOOCs has been turned the other way around where the communities themselves are able to share their indigenous know-how. The communities have surprisingly demonstrated intrinsic motivations of wanting to innovate and share their traditional knowledge, knowing very well that their children and friends will be able to access the content via the internet. The enthusiasm in seeing themselves in video recording has been an important contributor to potentially shape a future generation of MOOCs.

It has been important to make community participatory roles explicit in MOOCs so that the local knowledge is well-represented. The community has been levelled up as equal partners in MOOCs ecosystem in production, delivery, and consumption of learning materials. The participation allowed the community to switch roles as both teacher and learner where their local knowledge, their perspectives and outlooks are valued. It also recognizes their potential on par with the experts, and further raises their confidence.

The participation was enriched by the MOOCs' aligning the learning outcomes with the collective purpose of the community. The community is a heterogeneous mix of learners who have individual goals and share a fairly similar socio-economic background. Though their learning pursuit is driven by a need to achieve personal goals, they are bonded to each other in a common purpose to create benefit to the community. In fact, the communities were motivated to participate in MOOCs with the anticipation of learning outcomes that contribute to the preservation of local knowledge.

MOOCs should be able to allow the learners to experience communal core values while participating in the knowledge exchange. This means that the non-learners should also be equally supported and given the opportunity to reap the beneficial outcomes of MOOCs. With MOOCs there should be a mechanism to allow the community to control and filter the information that goes into the MOOC modules.

7. CONCLUSION

This research has presented a novel case of using MOOCs as a knowledge management platform to preserve cultural knowledge by redirecting MOOC from its current linear model to 'community led MOOCs' model. We have demonstrated that the knowledge sharing from elders to youths, most natural approach to sharing intergeneration knowledge for indigenous communities, can be reestablished by giving the community the center stage in producing MOOCs. It has further been shown that operationalizing the local learning loop, knowledge network and resources can produce outcomes that resonates the community core values of togetherness and collective benefits. Most importantly, the intrinsic motivation of being able to preserve knowledge and tradition is echoed as a strong enough a reason for indigenous communities to participate in MOOC for a social purpose, and a success behind such community led initiative. The possibility of using the current MOOC proposal as a platform for promoting knowledge preservation is therefore a promising area for future research.

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Computational Notebooks in Public Repositories

Speicher, Daniel and Cremers, Armin B.

Abstract: ***A computational notebook – most prominently a Jupyter notebook – is a special kind of a document that encompasses data, text, calculations, visualizations. Public repositories – most prominently GitHub – make them available. The number of notebooks is growing almost exponentially as more and more software developers, data scientists and machine learning students, teachers and engineers share their notebooks publicly. They use these repositories not only to store own notebooks but to find solutions to their specific problems at hand. The open exchange of computational narratives in Jupyter notebooks is an overwhelming success story. In this paper we ask the question of how the use and spread of publicly available notebooks affect the quality of code and its embedding in a computational narrative. Drawing on empirical studies and our own experiences in the creation of digital material to support machine learning education and our observation of students' use of notebooks, we comment on the quality. Our findings include that we cannot just reuse the concrete quality criteria that are in use for software in general. Much rather, we must integrate the competing demands in creating a linear computational narrative, thus adapting programming style and design patterns to the data science context.***

Index Terms: ***Code quality, Computational notebook, Education, Explanation, Exploration, Machine Learning, Project Jupyter, Public repository, Reproducibility***

1. Introduction

Computational notebooks have an overwhelming success story. The number of publicly available Jupyter notebooks on GitHub has grown exponentially in the recent years (see Figure 1). Perkel describes in his toolbox column in Springer Nature [2], under the title "By Jupyter, it all makes sense", the success story. The widespread use of Jupyter notebooks and the public discussions through scientific articles, conferences, and social media, created a broad awareness of their opportunities as well as the relevant limitations in tools and practices. Here we share in the endeavor of different research groups, who have taken on these limitations and are pushing the boundaries. Particular incentives come from the use of notebooks in data science and machine learning.

A "Jupyter Notebook is [a] web application that allows you to create and share documents that contain live code, equations, visualizations and narrative text." (https://jupyter.org/) The content of code cells is sent on demand to a Python session (called "kernel"), executed, and the output inserted below the cell.

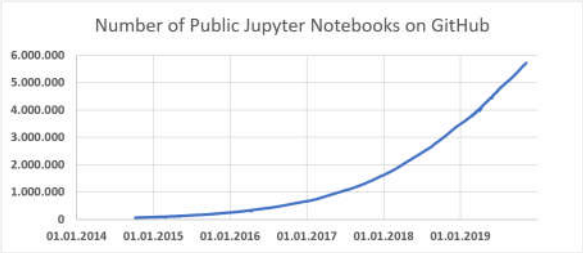

Figure 1: Number of Notebooks. The number of public Jupyter Notebooks on Github. according to the nbestimate project.

To provide an overall impression of a notebook, Figure 2 shows a screenshot of a larger part of a Jupyter notebook. We see a headline (in a Markdown cell), some code (in a code cell), two visualizations as result of the code, and some explanatory text containing even formulas written in LaTeX (again in a Markdown cell). The two rows of visualizations illustrate here the duality of two problems. The upper row shows a regular optimization problem while the lower row shows the minimum enclosing ball problem.

To illustrate the value of having LaTeX and actual Python code close to each other, Figure 3 shows another part of the same notebook. Having the formulas and the implementation so close to each other, makes it easy to check whether the code indeed implements the formulas

While GitHub offers the means to share and evolve the file, it needs another service called

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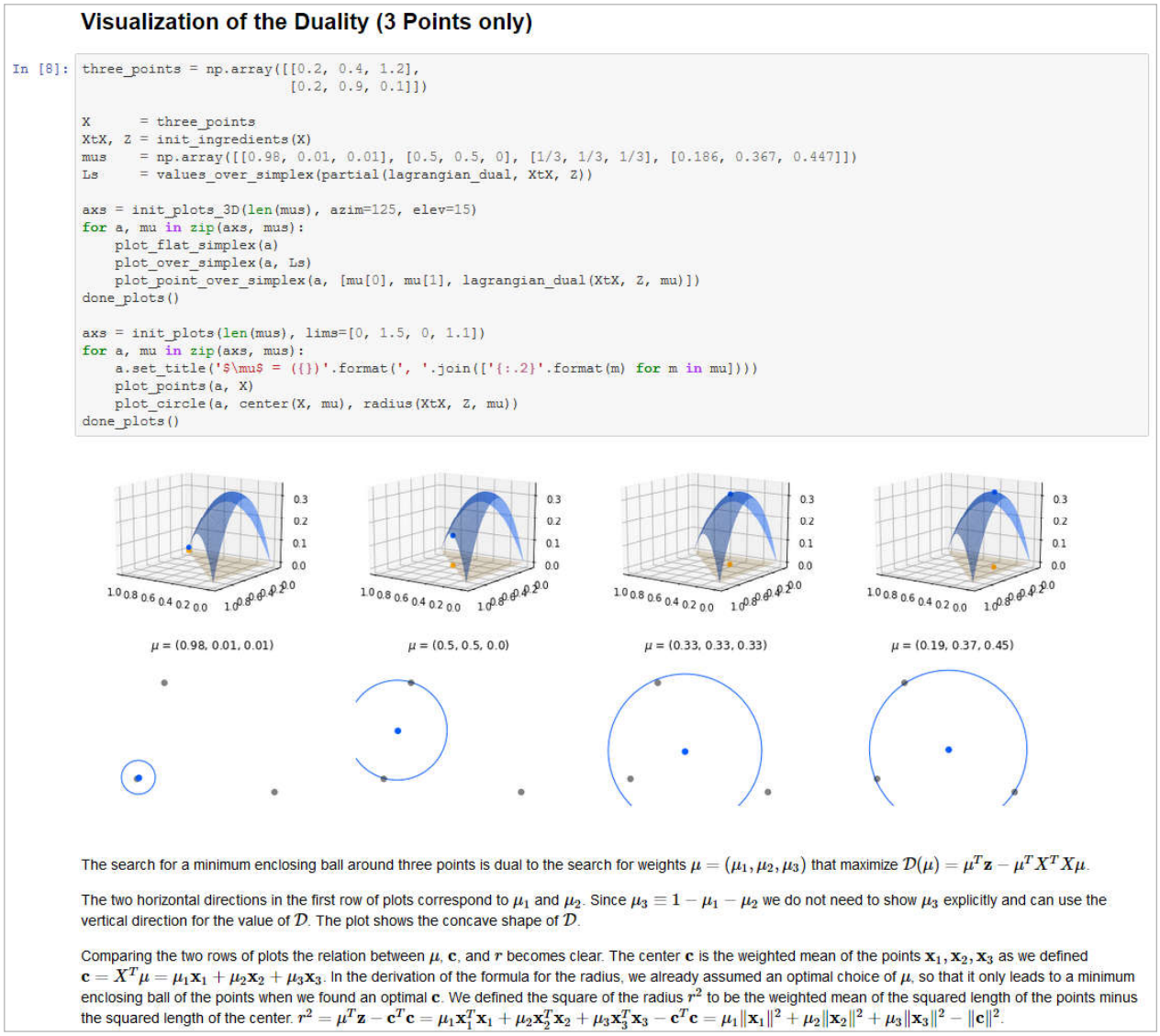

Figure 2 Jupyter Notebook. The Minimum Enclosing Ball Problem and a dual optimization problem. We show it here to give an impression of the different elements of a Jupyter notebook. (The notebooks is available online.)

nbviewer to display all aspects of the notebook correctly and it needs a third service called binder to use the notebook interactively. (See our notebook online on github, nbviewer and binder.)

2. PRELIMINARIES

$$\mathcal{D}(\mu) = \mu^T \mathbf{z} - \mu^T X^T X \mu$$

$$\nabla(-\mathcal{D}(\mu)) = -\nabla \mathcal{D}(\mu) = \mathbf{z} - 2X^T X \mu$$

```
def lagrangian_dual(XtX, Z, mu):
    return mu.T.dot(Z) - mu.T.dot(XtX.dot(mu))

def neg_lagrangian_dual_gradient(XtX, Z, w):
    return -Z + 2 * XtX.dot(w)
```

Figure 3: LaTeX and code. The math and the code do not translate immediately into each other, but the reader may infer their relation from comparing both with each other

There is one challenge in working with Jupyter notebooks that is worth mentioning upfront, and that is the impact of the execution order. It does not become apparent unless one observes how developers interact with notebooks. It is the strongest aspect of the criticism of notebooks in Grus' widely recognized presentation [3] and proved quite relevant in the empirical study that we will summarize in 3.2.

The result of a notebook depends on the execution order and may be impacted by hidden state. Let us illustrate this. A developer may have written the following four lines of code and executed the cell:

```
jupiter = 'Jupiter is '
emphasis = ', '.join(7 * ['so']); jupiter += emphasis
jupiter += ' wonderful!'
print(jupiter)
```

```
Jupiter is so, so, so, so, so, so, so wonderful!
```

After the successful execution of the cell, the developer realizes that she used the name of the planet but not of the notebook and changes the variable name and a string constant as seen

below. Executing the cell gives an unexpected result:

```
jupyter = 'Jupyter is '
emphasis = ', '.join(7 * ['so']); jupiter += emphasis
jupyter += ' wonderful!'
print(jupyter)
```

```
Jupyter is  wonderful!
```

What did happen? The result of the cell should have been the same. Just instead of “Jupiter” we wanted to see “Jupyter”. The developer had overlooked one occurrence of the variable `jupiter` in the second line. The mental model of the developer, the code read linearly, and the state of the Python process got out of sync. a) The developer thought there was just the one variable `jupyter`. b) The code shows a variable `jupyter` that is initialized in the first line and a variable `jupiter` that is *not initialized above* the place where it is read. c) The Python process knows a value of a variable `jupiter` that was *set in an earlier* execution:

```
print(jupiter)
```

```
Jupiter is so,  derful!so, so, so, so, so, so, so
```

Note how easily this error happens through well motivated changes to the code. The impact can obviously be substantial, and if we work with more complex data types like matrices, it is much harder for the developer to detect mistakes.

3. Empirical Studies

Two large empirical studies analyzed the publicly available Jupyter notebooks on GitHub.

3.1 Notebooks for Exploration and Explanation

Rule, Tabard and Hollan [12] analyzed approximately 1.25 million Jupyter notebooks retrieved from public repositories on GitHub in July 2017. These notebooks cover about 95% of the publicly available notebooks in the nearly 200,000 public GitHub repositories containing at least one notebook. The primary intention of the authors was to understand how people create narrative texts in notebooks to explain their findings. Nevertheless, they found that, leaving aside the quarter of the notebooks having no text at all, half of the remaining notebooks had less than 218 words. The authors suggest, as reason for the low amount of text, that many researchers “view their notebooks as personal and messy works-in-progress”. However, some (unfortunately the paper does give a more precise number here) of the notebooks with substantial text were judged to be “truly remarkable in the way they elegantly explain complex analyses”.

Notebooks thus allow for at least two substantially different uses. Fast feedback and the visible record of results are helpful to explore a problem and search for good solutions. An exploratory workflow nevertheless does not automatically lead to a notebook that effectively communicates the structure of the problem and of the solution. Creating a notebook that elaborates an explanation, requires additional effort and needs to take the intended audience into account. The step from exploration to explanation is substantial. Only recently some tooling for this transition became available, as we will describe below in 5.2.

From a programming perspective it is remarkable that little effort was made to modularize the code: Only 37.3% of the notebooks defined a function and only 12.3% defined a class. At least, 62.1% had comments in the code.

3.2 Reproducibility in Notebooks

One year later Pimentel, Murta, Braganholo and Freire [9] conducted a similar study with a stronger focus on reproducibility. This study, started out with 1.45 million notebooks created between January 2013 and mid of April 2018, found in them over 265,000 public GitHub repositories with at least one Jupyter Notebook. After filtering invalid, empty, or duplicated notebook files 1.16 million notebooks were left. The duplication detection compared only text and code and ignored metadata and results. A cloned notebook that had been executed again and delivered different results, but had otherwise not been changed, was thus considered to be still the same notebook. A case that is especially relevant for notebooks that are cloned by many students of the same course. Focusing on notebooks with Python code reduced the number to 1.08 million.

The study found similar results as [12] with respect to the distribution of notebooks to repositories, use of Markdown, definition of functions, and classes. Beyond the shared observations, it reports the following further insights: Users had chosen overall meaningful and long names for their notebooks. Judging by the imported modules, 1.54% of the valid Python notebooks contain tests. Over 85% of the notebooks did store some test results during their lifetime. However, more than about a million notebooks examined show that tests as such were done as was hoped in the right order, but often with skipped cells or out-of-order answers with the tests.

The authors attempted to execute the notebooks and to reproduce their results. The most common reason for execution failures were missing dependencies either because the dependencies declared in a `requirements.txt`, `setup.py` or `Pipfile` could not be installed or

none of these configuration files were given. In the latter case, notebooks were tested in a full Anaconda environment. In total, executability of almost 789,000 notebooks was tested. 24.11% of the runs were successful but only 4.03% produced the same results.

The reasons for failures were missing dependencies (29.23%: `ImportError`, `ModuleNotFoundError`), presumably out-of-order execution and hidden state (14.53%: `NameError`), missing data or absolute file paths (12.59%: `FileNotFoundError`, `IOError`).

These problems may be avoided by following certain good practices. The authors of this paper [9] give suggestions as part of the paper. The authors of the paper [12], discussed in the previous section, offer advice in the papers [10] and [11].

4. Code Quality in Notebooks

Coming from a Software Engineering background, we were substantially puzzled by the impact a medium notebook had on our programming style. Long standing rules as published e.g. in [8] or [16] seemed to be challenged. The following two sections are an elaboration of parts of our extended abstract [13].

4.1 Programming Style

Notebooks that were obviously developed with great care by other researchers showed similar styles as ours: Global variables are very common. Functionality was rarely encapsulated in functions or objects but provided by top-level statements. There was almost no information hiding. How did the medium shove us into following a programming style that every experienced developer would naturally frown upon?

On a second look it became clear, that the very idea of having a computational narrative presented as a linear sequence of cells, leads to this style. The global variables contain the data that the notebook sets out to analyze and some intermediate result. They are like the protagonists of the narration. The top-level statements describe what is done to these protagonists and ideally the result of the cell tells us the state they have reached afterwards. In contrast, a function definition has no immediate result beyond showing up as a defined function. It does not contribute to the state reached. Since the notebook presents a calculation, we do not want to hide information. As far as the code is only a minor detail, hiding it would still be nice.

By now it should have become clear that we cannot simply reuse established code quality criteria, but we need to take the goal of creating a linear computational narrative into account.

4.2 Design Patterns

While we cannot just reuse the concrete quality criteria we have for software in general, we may reuse how we find and describe good solutions. The notion of a design pattern being a “solution to conflicting forces in a context” (see e.g. Section 1.1. of [1]) is helpful. We will repeat three patterns that were already published in [13]. Our general context is a calculation presented as a linear narrative. We will only describe the most essential aspects of a pattern. The “forces” are all the conditions that are relevant to a certain design decision. The “solution” is a design idea that gives justice to all the forces.

“Function Exemplification” - *Forces:* We mentioned that a function definition itself does not immediately produce output and thus does not immediately contribute to the narrative. Nevertheless, a function is helpful for internal reuse, if for example the same calculation should be executed a few times with different parameters. Additionally, splitting a longer calculation into a few functions with intention of revealing names, may provide structure and help understanding.

Solution: Illustrate the use of the function in the next cell. Placing the call to the function in another cell separates the definition from the exemplification. Choosing the next cell keeps them close enough to communicate the connection. Giving such an example call should at least be possible for functions without side effects, short runtime, and easy to provide parameters.

“Updated Progress Line” - *Forces:* For regular software program code, progress information and results are presented in different locations. In the notebook everything is presented next to each other. Therefore, it is essential that progress information does not take up too much space once the calculation is finished. Nevertheless, if the calculation is long running, it is essential to get feedback about the progress. Only with progress information the user knows that the calculation is not stuck and how long she needs to wait for the result.

Solution: Let the calculation repeatedly overwrite only temporarily interesting progress information in the same line. `'\r'` positions the cursor at the beginning of the current line so that progress feedback can be given via:

```
print(
  'Progress: {} of {}.'.format(i, n),
  end='\r').
```

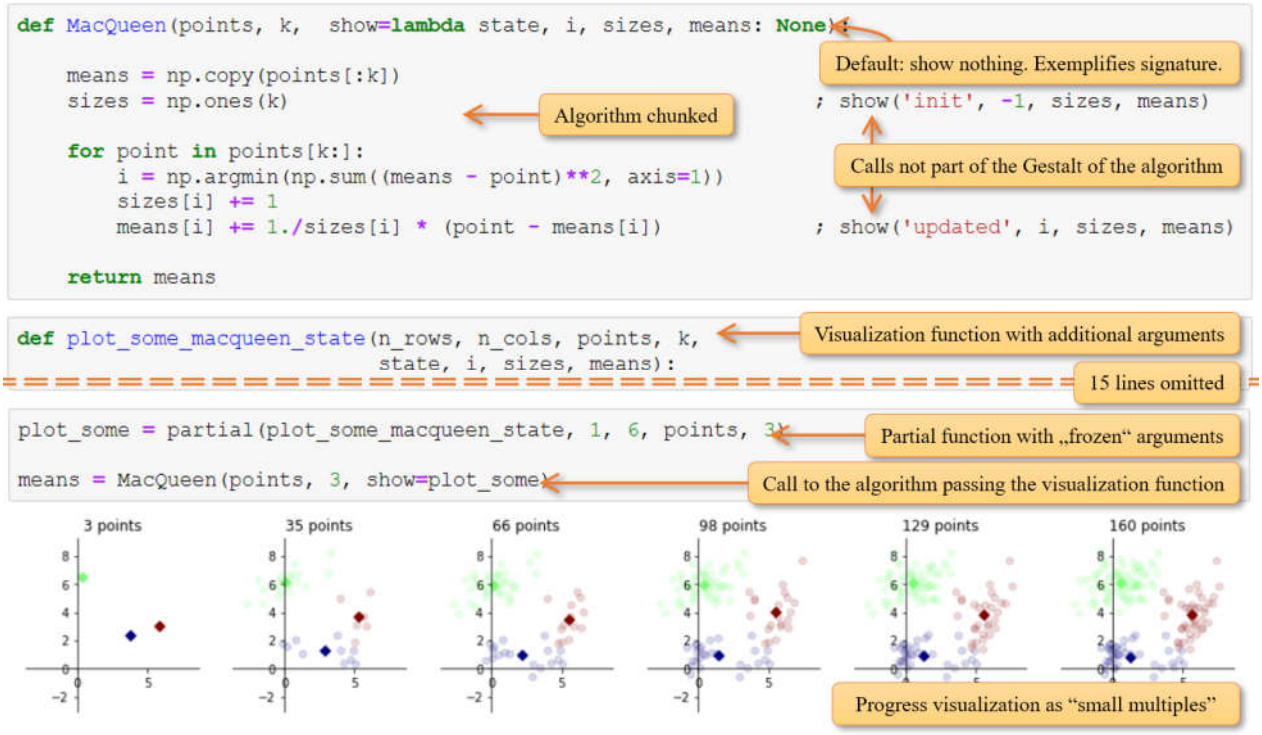

Figure 4: Visualization Callback Pattern. The implementation of MacQueen's k-Means algorithm is almost free of visualization concern and can be configured with different callback functions. Here we have chosen a function that creates plots for start and end state and a fixed number of plots in-between. The plots show the clusters with their means. (The notebooks is available online.)

Alternatively, different libraries have functions or objects providing the same effect. The essence of this pattern is a visual presentation of the progress information in limited space.

"Visualization Callback" - *Forces:* To illustrate an algorithm, its implementation should not be influenced by other concerns. In addition, we often want to show intermediate state of the algorithm. The same implementation should be usable with or without visualization. If it is not visualized, it should be fast. It is often interesting to visualize algorithms in varying detail and with respect to different aspects.

Solution: We pass a function as a parameter to the function that implements the algorithm. See **Error! Reference source not found.** for an example. As a default value this parameter gets an anonymous function doing nothing. The performance cost of invoking this function is below the cost of three integer additions (as discovered by experiment) and thus acceptable if not used in an innermost loop that contains otherwise extremely cheap calculations. The algorithm function calls the parameter function passing all potentially interesting information in. Visualization functions that do show something may have additional parameters that can be ``frozen'' by creating a partial function. If the functions were objects, we would talk about a "Strategy" Pattern with a "Null Object" as default strategy. If the space in the cell allows, we might position the calls further to the right so that they are pre-attentively perceived as separated from the algorithm.

Error! Reference source not found. shows the "Visualization Callback" in one of the notebooks we implement in our recent project [17]. The callback allows to keep the algorithm (here MacQueen's k-means algorithm) unconcerned with visualization. There is only the function parameter and the calls, separated by the layout. The callback is still able to produce a visualization consisting of small multiples (see page 67 in [14]) illustrating that the means move mostly at the start and reach plausible positions.

For long running computations the developer may choose a callback function that just generates an "Updated Progress Line".

A pattern is only a pattern if it is used frequently enough. We convinced ourselves that this is the case for the presented three patterns. "Function exemplification" is not only found in our own notebooks but even more consequently in notebooks of commercial deep learning courses. "Updated Progress Line" is not only a feature within our own notebooks but as well in the deep learning library Keras. "Visualization Callback" is a variant of the pervasive "Strategy" pattern and used at least four times with at least six different visualization functions in our own notebooks.

5. PUSHING THE BOUNDARIES

Based on the previous discussion and our lab experiences, we give an outlook on new developments like collaborative editing, a code gathering tool that extracts consistent code from explorational coding sessions, and some good practices.

5.1 The Benefits of Real-Time Collaboration – Observational Study: Remote Pair Work

While a notebook may be shared as easily as any other document, it was not possible to let more than one person edit it at the same time. Wang et al. report in [15] on an observational study of 24 data scientists working in pairs remotely either on a shared notebook ("shared condition") or on separate notebooks with the explicit permission to send code snippets or entire notebooks to each other ("non-shared condition"). The pairs were under both conditions allowed to communicate through further channels of their choice.

The pairs were given a "typical data science predictive modeling problem" to solve. Under the non-shard condition participants worked sequentially through the phases of 1) preparing, 2) cleaning, 3) modeling, 4) feature engineering and 5) submission. Under the shared condition the pairs worked in the same time overall twice through the phases 2) till 4). Working under the shared condition led to better prediction results (average 0.17 compared to 0.27), a higher number of models (6.17 compared to 3.00) and more lines (186.67 compared to 90.33). Only the percentage of annotation cells dropped slightly (19% compared to 20%). The key finding is that "working on synchronized notebooks can improve the collaboration outcomes by reducing communication costs and encouraging more exploration in a shared context."

5.2 Transition from Exploration to Explanation – In-Lab Usability Study: Code Gathering Tool

Head, Hohman, Barik, Drucker, and DeLine presented in [4] tool support for the transition from a notebook created during exploration to a notebook presenting an explanation. Speaking in reengineering terms their code gathering tool calculates the backward slice within the whole notebook history starting from interesting results as slicing criterion.

In more detail: While the data analyst interacts with the notebook, the tool records a history of the executed cells. When the user selects a result as a starting point for the gathering, the tool analyses the history backwards and keeps only those parts of the code that contributed to the result. This excerpt can then be exported into a new notebook or pasted into the notebook again. Note that this process reproduces the cells in execution order, even if they are in a different physical order in the notebook.

The authors conducted an in-lab usability study with 12 participants cleaning two given notebooks and executing an exploratory data analysis on another given dataset. The participants considered the possibility to gather code into a new notebook to be very useful (12/12 for the cleaning, 10/12 for the exploratory data analysis). The possibility to highlight lines the code depends on, was considered helpful as well (7/11 very useful, 10/12 at least somewhat useful). Reordering gathered code as cells was very useful to those, who used the feature during exploratory data analysis (6/7). We are convinced that the code gathering tool could be of high value to make the transition from exploration to explanation more seamless.

5.3 Practices

Not all steps to better notebooks need better tools. Some guidance can make a huge difference. Let us list Rule et al.'s ten simple rules published in [10] and [11]:

1) Tell a story for an audience
2) Document the process, not just the results
3) Use cell divisions to make steps clear
4) Modularize code
5) Record dependencies
6) Use version control
7) Build a pipeline
8) Share and explain your data
9) Design your notebooks to be read, run, and explored
10) Advocate for open research

Rule 5) helps to resolve the problem of missing dependencies prevalent in [9]. Rules 4) and 6) follow the demand for more software engineering in notebooks requested in [3]. To avoid the problem of out-of-order executions and hidden state it is furthermore recommendable to rerun the notebook and to even restart the kernel regularly.

6. CONCLUSION

Computational notebooks were created as a medium to present data science results as a computational narrative. Users found further use cases and stored their notebooks in public repositories. We shared our own insights into the specific quality criteria that result from the fact that the code does not only provide functionality but is itself already a message to the user. The public availability of the tooling as well as the notebooks open up to public both review for criticism and inspiration. Two empirical studies were able to identify shortcomings in published notebooks and suggest improvements. Research

groups took up the challenge to improve the tooling and provided advice on how to produce notebooks of good quality.

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Towards 3D Digitization in the GLAM (Galleries, Libraries, Archives, and Museums) Sector – Lessons Learned and Future Outlook

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Abstract: ***The European Cultural Heritage Strategy for the 21st century, within the Digital Agenda, one of the flagship initiatives of the Europe 2020 Strategy, has led to an increased demand for fast, efficient and faithful 3D digitization technologies for cultural heritage artefacts. 3D digitization has proven to be a promising approach to enable precise reconstructions of objects. Yet, unlike the digital acquisition of cultural goods in 2D which is widely used and automated today, 3D digitization often still requires significant manual intervention, time and money. To enable heritage institutions to make use of large scale, economic, and automated 3D digitization technologies, the Competence Center for Cultural Heritage Digitization at the Fraunhofer Institute for Computer Graphics Research IGD has developed CultLab3D, the world's first fully automatic 3D mass digitization technology for collections of three-dimensional objects. 3D scanning robots such as the CultArm3D-P are specifically designed to automate the entire 3D digitization process thus allowing to capture and archive objects on a large-scale and produce highly accurate photo-realistic representations. The unique setup allows to shorten the time needed for digitization from several hours to several minutes per artefact.***

Index Terms: ***photogrammetry, cultural heritage, 3D, digitization***

1. Introduction

In this paper we present a workflow, from photogrammetric acquisition in challenging environments to representation of the acquired 3D models in different ways, such as online visualization and color 3D printed replicas. Central to our workflow is the CultArm3D-P, a fully automated color-calibrated 3D-scanner able to scan arbitrary objects at reproducible high resolution at the push of a button. Our work lays the foundation for a full color end-to-end reproduction of artifacts. Our workflow has successfully been applied to several digitization projects of which we present a few results, such as a project in collaboration with the Bavarian State Archaeological Collection in Munich at the "Roseninsel" (Rose Island), an island in Lake Starnberg (Bavaria) where originals had to be replaced by 3D printed replicas due to humidity.

In another project with the Reiss-Engelhorn Museums in Mannheim we present results of what to our knowledge is the first ever automated photogrammetry-based 3D digitization of very small golden artifacts from the island of JAVA in Indonesia at very high resolution using a polarization approach combined with focus stacking.

We conclude with results and an outlook on the end-to-end reproduction workflow leading to virtual replicas (online 3D visualization, virtual and augmented reality) and physical replicas (3D printed objects).

2. Digital Cultural Heritage Strategy

The European Cultural Heritage Strategy for the 21st century should be geared towards the Digital Agenda, one of the flagship initiatives of the Europe 2020 Strategy, in order to further promote information and communications technologies (ICT) needed to preserve, enrich, and open up our cultural heritage and to ensure education and life-long training for the benefit of today's citizens and future generations.

Europe's cultural heritage is an "irreplaceable repository of knowledge and a valuable resource for economic growth, employment, and social cohesion" [1]. But despite its importance, cultural heritage is often at risk to be damaged and

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compromised in value, making innovative documentation and presentation methods increasingly important. This heightened relevance results from both the desire to provide better access to unique objects, e.g. to make museum collections more easily available to a wider audience or for research, and the looming threat of losing them due to disasters and other environmental influences. How fragile Europe's cultural heritage really is was made apparent recently by several natural and man-made disasters. Incidents like the fire at Notre Dame Cathedral in Paris, or - outside of Europe - the intentional destruction of the ancient Semitic city Palmyra, Syria, and the archaeological findings at the museum in Mosul, Iraq, underline the need for new methods of documentation and preservation and have led to a re-evaluation of the importance of high resolution facsimiles.

Digitization has proven to be a promising approach to create precise reconstructions of heritage objects for their digital preservation and virtual representation. Accordingly, EU Member States are called upon by the European Commission to increase their efforts for digital availability, online accessibility and digital preservation of their cultural heritage material. In 2011 already, the European Commission advised on the necessity of digitization and online accessibility of historic inventories as part of the Digital Agenda for Europe. Among other points the request for improved conditions underpinning large-scale digitization [2]. As one of the flagship initiatives of the Europe 2020 Strategy, the Digital Agenda further defined the preservation of cultural heritage in Europe as one of the predominant key areas in the context of promoting innovation, economic growth and progress through better use of ICT. Digitizing the Member States' cultural material and its long-term preservation is defined to be essential for access to culture and knowledge, to promote Europe's cultural diversity and to bring unprecedented economic opportunities.

Having proven to be promising and innovative, digitization enables a precise reconstruction of heritage objects for documentation and preservation. It also offers new ways of presentation that will change the cultural heritage domain: new visualization and interaction technologies allow heritage experts or curators to display and share museum collections or research results in novel ways both on-site in a museum setting as well as online. Especially the ways afforded to better present artefacts online, give heritage institutions in Europe the chance to achieve greater visibility for their collections and engage with a wider audience. Digitization offers a range of benefits to Europe's cultural heritage institutions and can therefore add value in the cultural heritage sector by enabling new forms of participation and a broad range of new applications, services, and business models in areas such as education and life-long training, tourism or gaming to attract new audiences and generate additional revenue streams:

Accessibility

To allow for global digital access to collections and research results. Numerous objects, of which only a fraction is displayed in museums, can be scanned, classified, and documented in online catalogues making them accessible to education and the public at large. Especially 3D replicas can be made available easily and therefore accessed by several researchers at once. Also, they pave the way for new research methodologies. For example, fragments of complex fossils can correctly be reassembled with the aid of 3D models or archaeologic objects scanned in situ and analyzed immediately.

Conservation

High quality 3D virtual models can be used by conservators as a reference for conservation and restoration measures on damaged goods and serve as a basis to generate physical replicas. Furthermore, a 3D model can help to precisely visualize damage patterns or worn areas and thus support better restoration decisions. In addition, high quality virtual exhibits can in many cases replace the shipping and loaning of originals to exhibitions, eliminating the risk of further deterioration due to accidental damages or detrimental environmental conditions and high insurance costs.

Documentation

Significant pieces of art, which are endangered by environmental influences or even irrevocably destroyed by disastrous events may at least be secured in their current state of conservation and made accessible for research around the world. In case of the loss of an original, the image, form and context can be made available for scientists and interested parties due to photo-realistic 3D models. With the aid of such digital '3D conservation', objects remain accessible for subsequent generations.

New exhibition formats

Digitization (2D and 3D) enables new ways of exhibition planning and implementation through virtual museum experiences. Collections spreading over multiple museums can be showcased concurrently at different geographic locations. Virtual reproductions can be used in hybrid exhibitions and create innovative and interactive visitor experiences. Collections and

exhibits become accessible for visitors from anywhere in the world and enable new ways of interaction with collections

New Applications and Services

3D replicas e.g. can be used for the development of apps, games, documentaries, tourism services, and educational content and can thus ensure a more intense visitor experience, new forms of participations, and additional revenue streams.

3D print

3D replicas can be used in printed form as exhibition and loan objects for various purposes (i.e. to avoid damages and insurance costs or legal uncertainty relating to ownership). Not only delicate or particularly fragile artefacts, but also those too valuable for transport or loan, lend themselves to the creation of copies true to the original. High-precision printing models developed from the collected 3D data can serve the physical reproduction of destroyed or fragmented cultural heritage goods.

3. CULTARM3D-P

In this chapter we describe the first step of an automated end-to-end pipeline from 3D capturing to display and 3D-print. We call it the CultArm3D-P, a fully automated color-calibrated 3D-scanner able to scan arbitrary objects at reproducible high resolution at the push of a button.

The motivation for this scanning station is to relieve the human operator from tedious tasks, such as repositioning a camera around the object and keeping track of the scanning progress to eventually ensure a complete surface coverage and stable quality. Those are challenging tasks even for expert scanning operators, especially for high resolution scanning where the scanner measurement volume (defined by the camera optics) is normally a lot smaller than the object itself, and thus the resulting high-resolution 3D model is comprised of many single scans or images. The impact of this scanning station is twofold. Firstly, the overall scanning time is effectively reduced by a high data acquisition rate with automated and parallel processing. Secondly, the automated and adaptive data acquisition enables economical use of focused camera optics, such as macro lenses. This allows the scanning task even for larger objects, and thus effectively increases resulting surface resolution and 3D model quality.

In the following subsections, first a component overview of the scanning station is given, followed by an explanation of its virtual representation that serves as a planning environment. Then, after a description of the camera image acquisition and the reconstruction of 3D models, the focus is on the technique of view planning that involves all prior steps in a feedback loop to enable the scanning station to operate autonomously.

3.1 Design and Component Overview

The components of the CultArm3D scanning station can be classified into capturing and positioning devices, which are synchronized and controlled by a standard PC. For capturing, a high-resolution photo camera is combined with a customized mounted ring light and an optional background light. The camera must feature a PC control interface for triggering and transferring the images, such as the Canon 5DS R (50MP) or the PhaseOne iXG (100MP). For positioning, a light-weight robot arm holding the camera is combined with a turntable for the object. Thus, the object can be captured from all sides while movements of the camera can be restricted to one side of the turntable and the robot arm is not required to reach over the object for capturing it from the other side, resulting in a safer workspace and enabling the use of a static photo background. The positioning devices must also feature a near real-time PC interface, such as the collaborative robot arm series from Universal Robots.

Fig 3.1.1: CultArm3D-P as desktop version

There are currently two versions of CultArm3D scanning station available, one light-weight compact desktop version (see figure 3.1.1) and one heavier out-of-box version that comes with a centerless glass turntable. While the first version features a space-saving flat turntable, second version enables capturing the object even from below through a glass plate in one scanning pass without having to reposition it. This further reduces manual interaction with, e.g. fragile objects that cannot simply be repositioned upside-down or sideways.

Fig 3.1.2: CultArm3D-P front and back light

The custom designed ring-light has a D50 spectrum suited for color calibration with attachable polarization filters for capturing shiny or other challenging objects without specularities. The ring-light is used at close distance to illuminate and dissolve even cavities while the automated surface-adaptive robot motion guarantees a steady distance to the area in focus and thus a uniform light intensity throughout the whole scanning task. An active backlight can be optionally installed to support object segmentation from the background. Figure 3.1.2 shows both lights in operation, the ring-light at close focus distance and the back light for capturing the object's silhouettes from far distance.

3.2 Virtual Representation and Planning Environment

All relevant hardware components are spatially modelled and integrated into one virtual 3D monitoring and planning environment (see figure 3.2.1). The viewer shows the actual robot pose and the resulting camera angle by processing essential robot sensor readouts in near real-time and combining them to a human conceivable virtual 3D representation of the present reality. Furthermore, future scanning actions are planned and visualized (as a green transparent overlay). Intermediate scanning results are displayed within the cylindrical object safety volume (orange transparent overlay) and updated as soon as they are reconstructed and become available to provide a visual preview and indication of the scanning progress.

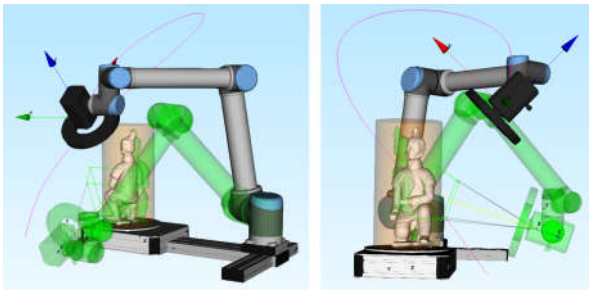

Fig 3.2.1: CultArm3D planning environment

In particular, techniques of analytical forward and inverse kinematics are applied to plan transitions between consecutive camera views and the implied robot trajectories in a safe and time-efficient way. For this reason, all vital robot parts are also augmented with colliders, i.e. surrounding geometric primitive, for rapid prediction and avoidance of collisions (see figure 3.2.2). In this way, camera views that would compromise the object's safety are either automatically rejected or rearranged [3].

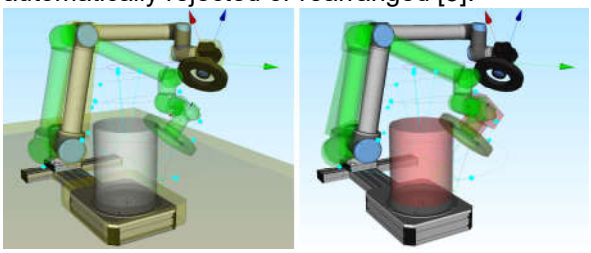

Fig 3.2.2: Trajectory planning with collision detection and avoidance (left: surrounding colliders in yellow, right: detected collision in red)

3.3 Initial System Calibration

To further increase the precision of the planning and scanning results, the previously defined and modelled spatial transformations from the virtual 3D representation between different parts (such as turntable, robot, and camera) are refined and corrected by an additional geometric calibration phase.

This scanning station is mobile deployable and quickly installed at new scanning locations with different camera lens combinations. However, this usually requires to temporarily unmount the camera using the quick release adapter, or to detach the robot arm from the turntable for compact packing, and this will result in a slight change in the spatial transformations and camera intrinsics when reassembling parts of the station. Therefore, the CultArm3D scanning station can compensate for this change by an initial system self-calibration that automatically carries out the following three steps in order:

1. Camera intrinsics calibration
2. Hand-eye calibration
3. Turntable calibration

First the camera intrinsics are retrieved based on [4] defining the actual field of view and compensating the lens distortion. Next the hand-eye transformation between the camera's optical center (eye) and the robot's tool frame (hand), where the camera is mounted at, is retrieved based on [5]. Using the robot arm limp calibration, which is usually provided by the manufacturer, the optical center of the camera can now be positioned with respect to the robot arm base. In order to position the camera with respect to the object on the turntable, a final step, the turntable calibration is carried out to find the surface and the rotation axis of the scanning volume. All essential calibration data is automatically acquired after placing a calibrated ring-board target on the turntable.

After the geometric calibration is complete, the camera is characterized for color by replacing the

calibration target with a known color board (such as X-Rite ColorChecker SG for normal setup or Rez Checker Target for macro setup) and capturing it within the scanning volume at the desired fixed focus distance with the ring-light illumination.

3.4 Image Acquisition and 3D Reconstruction

The CultArm3D scanning station reconstructs 3D models using the established technique of photogrammetry. Therefore, the acquired raw data consists of high-resolution photos of the object, covering each surface part several times, in order to use structure-from-motion [6][7] and multi-view-stereo [8][9] techniques to recognize features and triangulate 3D information. In general, for a set of photos with complete surface coverage, the higher the camera image resolution, the higher the resolution of the resulting reconstructed 3D model. Hence, for highest resolution focused camera macro optics can be applied even for objects much larger than the actual camera measurement volume (defined by field of view and depth of the field) and capturing only a small part of the object surface per image but in high resolution. The drawback of this method is that, because of the small measurement, much more photos are necessary to cover the complete surface. This trade-off between time and quality is addressed by this scanning station.

At the current state the CultArm3D scanning system captures a high-resolution image in average every 4 seconds (approx. 900 images per hour). The images are directly transferred via USB3 connection and stored in a project folder for further processing. For small camera movements between views, e.g. during focus stacking, the system's acquisition speed becomes mostly limited by transfer speed of the camera. To achieve this high acquisition rate a state machine is modelled in software that synchronizes different hardware and software components, such as camera, lights, robot arm and turntable, reconstruction, view, and trajectory planning modules. Images are captured and processed in groups, allowing for parallelization, e.g. capturing the next group while processing the previous group.

In comparison to other 3D reconstruction techniques, such as structured-light or spacetime analysis for laser triangulation, photogrammetry is computationally expensive, normally resulting in long processing times of several hours for the final full resolution model. Therefore, the final 3D model in highest quality based on the full resolution images is usually calculated offline after the data acquisition process with the automated scanning station finished. In order to predict an adequate reconstruction quality for the final model and ensure complete surface coverage, intermediate low-quality 3D models are reconstructed in clusters already during the scanning task and they serve as a quality indicator and a decision base for further scanning actions.

3.5 View Planning

Especially in the cultural heritage domain, objects are very unique and vary in size and shape. Therefore, the scanning strategy and the camera views cannot be simply predefined but have to be carefully adapted to the individual object to achieve best results.

In this scope, view planning describes the process of computing a sufficient set to camera views in position and orientation that captures the object of interest as completely as possible, resulting in a 3D model with the desired quality [10]. This can even be an incremental process involving a feedback loop of planning, capturing, and reconstructing, where the intermediate incremental reconstruction serves as the input for the next planning phase. It can also be regarded as an optimization problem, with the objective function of maximizing an overall model quality estimate while satisfying the safety constraints. The challenge however lies in the definition of a proper quality estimate that can be frequently evaluated during the scanning process and predicts / correlates with the desired quality of the final 3d model.

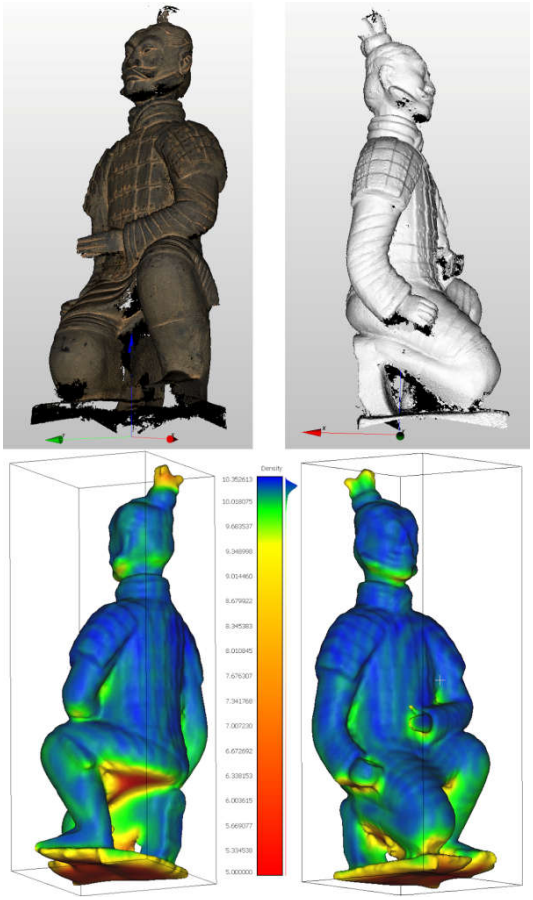

Fig 3.5.1: Intermediate 3D reconstruction results with surface density estimation

The CultArm3D features a hybrid approach that relies on little initial user input of setting a bounding and safety volume by defining a cylinder in height and diameter around the object on the turntable. Then a first set of approximated views can be quickly calculated and carried out mainly based on the volume size, the camera field of view and focus distance. Figure 3.5.1 shows the intermediate reconstruction result from an initial quick scan with 40 images reduced to low resolution. The point cloud density is automatically evaluated and low-density areas and holes are identified (and highlighted with red color) and can be distinguished from areas with sufficient density (blue color).

Based on the intermediate 3D reconstruction, a second more detailed set of views is planned utilizing rendering technologies and the calibrated camera intrinsics to simulate the effect of each view candidate. Figure 3.5.1 shows how the camera depth of field is visualized on the object. The view candidates are selected in such a way that the area in focus, which correlates with the local density gain, is maximized. Special attention is given to the previously identified low density areas that are often caused by occlusions. Additional views candidates are generated targeting those areas to eventually reach a sufficient density. With this new set of selected view candidates, the next scan phase can be carried out by the robot and the intermediate 3D reconstruction is updated. The process repeats until the desired surface density.

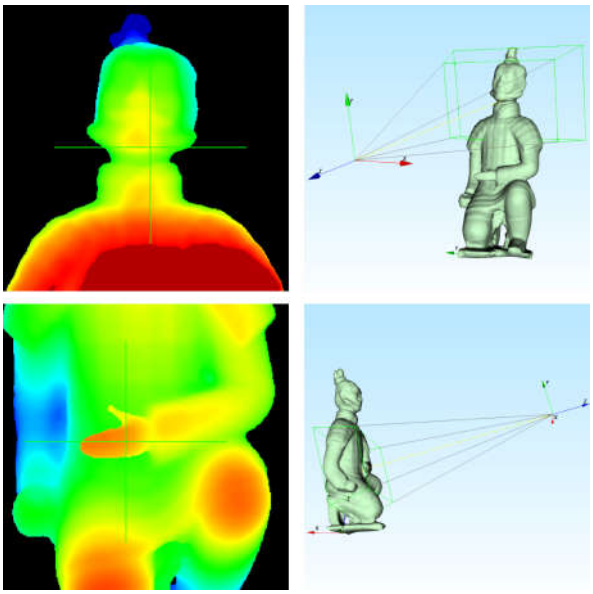

Fig 3.5.2: Depth of field estimation of two camera view candidate (green: optimally focused, blue: far plane, red: near plane)

A strong correlation was found between the density estimate on an intermediate point cloud and the surface quality of a resulting final 3D reconstructed with images in full resolution. Furthermore, careful focus planning is essential to the quality gain of intermediate and final 3D model, especially because the use of lens autofocus focusing functionality is not recommended for photogrammetry because it changes camera intrinsics for each view resulting in incomparable camera images. Therefore, the lens focus stays fixed throughout the whole scanning task while the robot automatically adapts the distance to the surface with respect to the selected camera view candidate.

4. RESULTS

In this chapter we present the results of some challenging digitization projects and our workflows.

4.1 "Roseninsel" – Starnberg Lake, Bavaria

The Rose Island is a small island in the Starnberg lake in the state of Bavaria, where the royal villa, the "Casino", was built in 1853 on request of the king of Bavaria, Maximilian II. He was a passionate collector of antique findings, which he was showcasing in the dining room of the Casino [11].

While the association "Der Foerderkreis Roseninsel Starnberger See e.V." aims to restore the "Roseninsel" island to its original state, the Bavarian Palace Department does not support this objective due to numerous reasons - fire protection, possible damage caused by visitors, and thus insurance-related questions that stand in the way. Therefore, they took the decision to commission Fraunhofer IGD to create 3D replicas of five original exhibits in cooperation with the Archaeological State Collection and display them instead.

Fig 4.1.1: Roseninsel original objects.

The CultArm3D-P table-top version is designed to acquire 3D data of cultural heritage objects up to a size of 40cm. Images were captured with a Canon camera system (Canon 5DS R, EF 100mm Macro USM), which was mounted on a lightweight robot arm. Lighting environment was realized with two large softboxes to ensure soft homogenous illumination of the objects. Objects were placed on a turntable, which was synchronized with the capturing system. The system captured around 400 images, which were later used in image-based 3D reconstruction.

Fig 4.1.2: Original Oil Lamp / Virtual color-calibrated Oil Lamp.

The complete workflow for photogrammetric 3D reconstruction consists of three main steps:

1 Calibration: Intrinsic camera calibration and color calibration through ICC profiles (characterization of the image sensor for a specific lighting environment).
2 Image acquisition: The autonomous scanning system calculates camera positions using next-best-view planning for the individual shape and size of the object automatically.
3 Processing: Captured RAW images are converted to sRGB color space based on the ICC profile generated during calibration. Image masks are automatically generated based on the image background and sharpness of the image and applied to remove the image background content. The data from all previous steps is used in the image-based 3D reconstruction workflow, which involves Structure-from-Motion, Multi-View Stereo, Surface Reconstruction, and Texture mapping.

Fig 4.1.3: 3D-replicas using Cuttlefish 3D printer driver.

The 3D printing workflow loads a textured 3D model and computes the material arrangements encoded as 2D image slices to control a multi-material photopolymer 3D printer. We used a streaming-based pipeline in which sRGB-textures were loaded, the model was voxelized, sRGB colors were transformed into CMYK tonals using an ICC color profile for each voxel, 3D halftoning of CMYK tonals was applied to each voxel and finally 2D image slices of print material arrangements were sent to the 3D printer's firmware to be printed.

The pipeline was encoded in Cuttlefish (Version 2016) [12] and used by the 3D printing service Alphacam [13] that printed the models.

4.2 JAVA Gold – rem Mannheim

Gold is extremely difficult to digitize due to its highly reflective material properties. In a project with the Reiss-Engelhorn Museums in Mannheim, Germany, we used our CultLab3D-P scanner to capture 20 very small gold artifacts from the island of Java in Indonesia, ranging from rings, earrings to bracelets in extremely high resolution with faithful color reproduction, so they would be displayed on 65" autostereoscopic displays in the exhibition showing their creators' craftsmanship and enormous attention to detail.

Fig 4.2.1: Java Gold Exhibition: Earring with mythological Daemon, Java 14.-15. AD.
© CES / 3D-model: Fraunhofer IGD.

The reason why highly reflective surfaces are so hard to digitize, a problem equally found in structured light systems and the image-based approach of photogrammetry used by CultArm3D-P, is that both systems draw their knowledge of geometric depth from triangulation that is based on active or passive coding of the

target surface. In the first case, structured light is overlaid over the surface to allow spatial decoding, and thus a correlation of points on the encoded surface and the corresponding pixels in the camera image. In the second case, fine structural patterns already existing on the object surface found in one image are identified on the same exact surface location, observed from several different camera perspectives, again serving as a basis for correlation of surface points and camera pixels for triangulation. In the case of reflective surfaces, the signal cast on the object surface, be it structured light or simply diffuse light required for photogrammetry, is reflected back to the camera, leading to overexposure of the sensor. Reducing exposure time, closing the aperture or reducing the light source intensity still leaves bright sensory readout in the regions of high reflectivity, depending on the camera and light angle in relation to the surface normal, while other regions are underexposed, leading to no usable correlation information. Instead of trying to find a suboptimal tradeoff between the components involved, we simply separate the received light feedback into the desired (diffuse) component, and the undesired (specular) channel. We can then use the purely diffuse information to extract geometric information, while entirely shutting out the specular compound. We achieve this by exploiting the physical effect of circular polarization, which is also used in photography. The effect only exists for mostly parallel light and observer direction (camera), which additionally implies that the light source must be as close as possible to the camera. We satisfy this requirement using diffuse ring lights of our own design which surround the lens, providing a narrow band of diffuse light around the lens aperture. Both the light source and the camera lens are equipped with circular polarizers that are tuned so that they let the diffuse light component pass while blocking the specular component. The effect is based on the fact that light originating from the light source and being directly reflected off the target surface is phase-shifted during the reflection, and cannot pass the polarizer in front of the camera (analyzer) which is tuned accordingly. All other light contributions that are reflected by the surface but find their way under different angles and numbers of reflections, pass the analyzer, and contribute to a well-lit diffuse image.

Fig 4.2.2: Java Gold Exhibition at Reiss-Engelhorn-Museen; © CES / 3D-model: Fraunhofer IGD / United Screens GmbH.

5. CONCLUSION

We presented our CultArm3D-P, an autonomous, color-calibrated 3D scanning robot yielding reproducible high-quality 3D models as an example of how to put automated 3D mass digitization for the digital preservation of entire collections to practice. In line with the overall objective of the European Commission's Digital Agenda for Europe, our approach provides a solid foundation for future research and development of 3D technologies in the realm of cultural heritage. The system is highly flexible and can come in multiple configurations using glass turntables to scan from below or turntables on the floor to increase the scanning volume and allow for heavier artifacts. It serves as a platform for future improvements and the inclusion of advanced technologies (e.g. volumetric measurement sensors, ultrasound or others) towards 3D consolidated data models and therefore represents an important contribution to leveraging innovative digital technologies for the cultural heritage sector. The conducted work marks an important milestone in the journey of cultural heritage research towards a connected and digital future. It fosters new applications using high-quality 3D models which range from better visitor experiences in museums by innovative exhibition concepts based around 3D replicas, to new business models such as 'virtual loans' of 3D models or educational applications. Our CultLab3D developments offer the chance for cultural institutions to tap into additional revenue streams and secure their funding with complementary business models and enable digital heritage preservation and research for future generations to come.

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Potential of Bots for Encyclopedia

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Abstract: ***The wide range of applications and the capability to process and understand natural languages made chatbots very popular. Besides that, many applications chatbots are also used as information retrieval tools. Chatbots are changing the way users search for information. This document focuses on a chatbot that is used as an information retrieval tool. The chatbot enables information search in natural language in a geography domain. In case of a large number of search results, the chatbot engages users with clarification questions. It also provides support to users when uploading multimedia content to the website.***

Index Terms: ***chatbots, information retrieval tool, information search***

1. INTRODUCTION

Austria Forum is an online encyclopedia, an online collection, that provides Austria related information. The content of Austria Forum is divided in several categories and written in English. The category of interest for this work is the geography category. It offers information about all countries of the world. Each country page includes general information and links to category pages. Each category page stores data presented in form of text, tables or pictures. The "Community Contributions" category provides forms for uploading interesting pictures, video and audio clips.

It is known that online encyclopedias provide a large amount of information. The information search on an online encyclopedia can be illustrated in two scenarios. The first one is to navigate through the website using links between individual pages. The second, more common way, is to use the search engine integrated in the website. The search engines are mainly based on keyword matching algorithms and provide a list of results when supplied with an input. In order to find desired information, the user needs to browse the list. No matter which of the ways is chosen, the information search is time consuming. The relevance of the information retrieved is questionable. As stated in [1], finding relevant information has always been an issue since the first search engines were built.

This publication is about design, architecture and development of the chatbot prototype for Austria Forum that can be used as an information retrieval tool. The purpose of the chatbot is, on the one hand, to enable information search in natural language and, on the other, to guide users when uploading content to the website. Using natural language, users are able to express their needs better and more accurately; and using natural language processing and understanding, the chatbot is able to understand what users are searching for. Users participate actively in information search providing answers to clarification questions and thus contribute to the relevance of search results. The chatbot requires additional information in cases of ambiguous questions or a large number of search results. In terms of upload of content, the chatbot engages users with a finite number of questions in order to gather needed information.

The main focus of this work will be on improving the relevance of the search results and a faster access to information.

2. ABOUT CHATBOTS

Chatbots are software programs that enable users to chat, communicate, and interact with them in natural languages. They are also called dialog-based systems, virtual assistants, conversational agents or machine conversation systems depending on the area of deployment. [2]

Chatbots were primarily built to amuse and entertain the users. ELIZA was the first conversational system that was developed by Joseph Weizenbaum in 1966. The system was programmed with scripts and based on pattern matching algorithms. The goal of ELIZA was to imitate human conversation. Later in 1972 the psychiatrist Kenneth Colby developed a chatbot called PARRY, which used to simulate a paranoid individual. In 1995 a chatbot named ALICE was developed and used to entertain users. ALICE is an open source software and can be used to build customized bots. [2], [3], [4], [5]

Many chatbots developed in the last 50 years were inspired by ELIZA. Though ELIZA was limited and did not provide real understanding,

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users still wanted to communicate. It gave them the feeling that they were talking to a real person. This was the reason for the increased development of chatbots. In the 90s the Leobner Prize, a contest where chatbots performed the Turing Test, was founded. The Turing Test is a method proposed by Alan M. Turing in 1950 for measuring intelligence of a computer system. The Leobner Prize had a big impact on developing chatbots and the Turing Test has increased the interest in the area of artificial intelligence (AI). [6], [7]

In 2015 the attraction to develop chatbots intensified because the use of messaging applications surpassed the use of social networks. Big companies launched platforms for bot development and integration. An increased amount of data on the internet and improvements in data processing and machine learning enhanced artificial intelligence. It is possible to develop more complex chatbots that can execute multiple tasks. Additionally, the range of chatbot applications has widened. Nowadays chatbots are used for customer service, marketing, finance, human resources, e-commerce or entertainment. [8]

The type of a chatbot depends on various parameters. The categorization can be performed based on knowledge domain, service, goal or methods for input processing and response generation [6]. The conversation length is also a possible parameter to perform the classification of chatbots. Some chatbots tend to engage users and have long conversations. These chatbots are able to recall earlier conversations and determine the context of the current conversation. Short conversations are characteristic for chatbots which provide some sort of information when supplied with a question.

The information retrieval is also a field where chatbots find their application. The chatbots to question answering (QA) systems and the chatbots to frequently asked questions (FAQs) attract attention. QA systems tend to provide answers when receiving a query in contrast to search engines that deliver search results in form of lists [3], [9]. As stated in [9] a chatbot can be used as an interface to an open domain QA system. Bayan Abu Shawar presented a chatbot that is used as a natural web interface to QA system [3]. ALICE bot was retrained to be able to answer university related FAQs. The chatbot is designed in such a way that it can be used to provide answers to FAQs of any university [10]. Another example is the chatbot based on ALICE that was trained on FAQs of the School of Computing at the University of Leeds [4]. Natural language systems were already built to provide access to semi structured data of yellow pages [11].

3. Prototype Implementation

The chatbot for Austria Forum is a standalone application developed with Java 8 technologies and runs on the Tomcat Apache server. The knowledge base of the chatbot stores information retrieved from the geography part of Austria Forum. The chatbot architecture consists of a client and a server side. The communication between the client and the server is enabled with the help of Java API for Web Sockets. The server side communicates also with a natural language understanding (NLU) platform, called Dialogflow.

The following should clarify how the chatbot basically works. When the chatbot is invoked in a browser, a single client page is displayed. The conversation starts when a user enters and sends a question. The user input is forwarded to the chatbot system running in background. The chatbot then performs input processing and searches for keywords and location information within the input. Subsequently, the user input is sent to Dialogflow for entity and intent recognition. The response from the NLU platform, which is sent in JSON string, is parsed. Having the parsed information, the chatbot knows what the user is asking for. It either creates a query based on the parsed information and performs a search, or engages users with questions and gathers information needed for the upload. In the case of a search, the search results are retrieved. If the number of results is within a defined range they are displayed to the user. Otherwise, the chatbot activates a conversation context and engages the user with clarification questions, collects information, updates the query and performs the search again. This procedure is repeated until the results are displayed to the user, or the chatbot cannot not find any information in the knowledge base. In the case of an upload, the chatbot activates a conversation context and verifies if the entered information corresponds to the requested format. If the verification is successful the chatbot uploads the information to the website. Otherwise, the chatbot notifies the user about the failed verification and is ready to process the next question.

3.1 Design

The design of the single client page was kept as simple as possible. It was developed using HTML, CSS and JavaScript. The client page, as can be seen in Figure 1, includes an input text field, a send button, and a conversation history field. The important thing is that a user does not need additional knowledge in order to communicate with the chatbot. The design of the client page is similar to commonly used conversational interfaces in messenger applications.

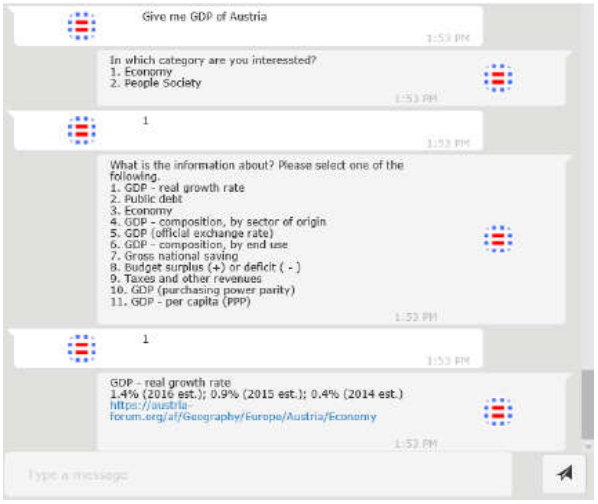

Fig. 1. Single Client Page

The knowledge domain represents an essential part of the chatbot. As stated in [6] there are two kinds of chatbots when considering the knowledge base: open domain and closed domain. With an open domain chatbot, the conversation can go in any direction. Closed domain chatbots are limited and can provide answers regarding one specific topic [3]. Since the chatbot for Austria Forum uses the geography website as an information source, it can be considered as a closed domain chatbot.

The information on the geography website is accessed over API and retrieved in JSON format. The JSON objects differ in content, structure depth and nested fields. Therefore, an auxiliary tool had to be developed to structure JSON objects. Each JSON object represents a chunk of information. This step was made in order to facilitate analyzing, searching, and editing of the knowledge base.

The natural language understanding (NLU) platform called Dialogflow is used for input understanding. Previously, the platform was launched under the name api.ai. Dialogflow is an artificial intelligence platform based on machine learning. It is owned by Google and includes built-in agents, which can be seen as modules required for natural language understanding. The agent “geo search” was created in order to handle text input forwarded from the chatbot system. The agent functions based on entity and intent concepts. The entities represent a chunk of information in a user input. In addition to built-in entities (e.g. date, number, city, country), custom entities were defined (category, continent). An intent can be seen as a mapping between a user input and possible responses. It helps to understand what users are searching for. The “geo search” agent has seven intents categorized in two groups, the “search” and the “upload” group. The intent groups help the chatbot understand when users want to search and when to upload information. The platform provides user interface for agent training process. It is possible to provide conversation examples and, in this way, improve the agent understanding. Of course, the agent is able to learn with the time and become more intelligent.

3.2 Architecture

Each chatbot follows a defined flow that begins with a user input and ends with displaying of answers. The chatbot for Austria Forum follows the general pipeline [6]. The first stage of the pipeline is concerned with input processing, followed with input understanding where named entity and intent recognition is performed. The last two stages deal with information retrieval for the response or candidate response generation, and selection or generation of the response. The architecture of the chatbot system for Austria Forum includes four components as illustrated in Figure 2: natural language processing (NLP), natural language understanding (NLU), search, and logical component.

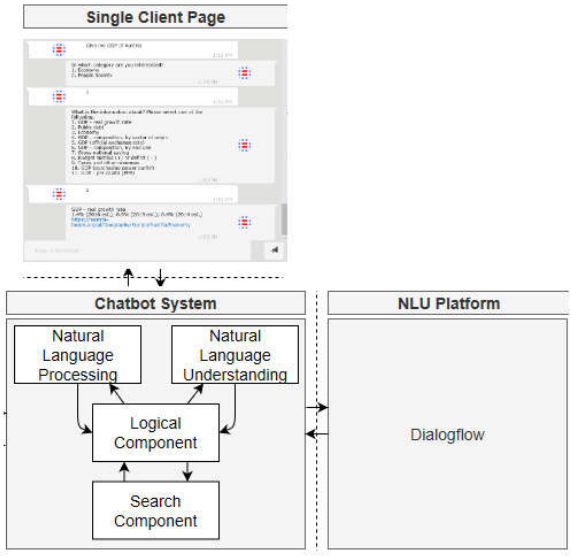

Fig. 2. Architecture of the chatbot

The Natural Language Processing Component is based on the Stanford CoreNLP software library. User inputs are passed through the pipeline of different tools that perform tokenizing, sentence splitting, part of speech (POS) tagging, parsing, named entity recognition (NER), and lemmatization [12]. The main task of the NLP component is to extract keywords and location tags. The results of the POS tagger are used for keyword extraction. This tool provides over thirty different tags. The main focus was on location tag extraction since the knowledge base includes geographical information. Location extraction was performed with the help of named entity recognizer. For English, NER recognizes person, location, and organization entities. How these two

tools work is shown in an example question in Figure 3 and Figure 4.

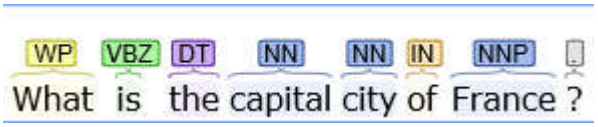

Fig. 3. Part of speech tagger

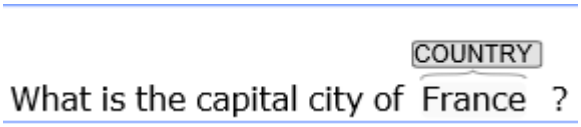

Fig. 4. Named entity recognizer

During the time of the research an evaluation of the Stanford CoreNLP and the Apache OpenNLP libraries was conducted. The number of the provided tools is almost the same. Apache OpenNLP uses different models for the POS tagger and NER tools, whereby CoreNLP needs only one model for its tools. The POS tagger of CoreNLP delivers better accuracy and takes less time than the POS tagger of OpenNLP. [13]

The Natural Language Understanding Component is used to extract meaning from the user input and makes it understandable for the chatbot. The component communicates with Dialogflow where entity and intent matching is performed. The response from Dialogflow is retrieved in JSON format containing detected entities, matched intents, actions, and parameters. Having this information in addition to keywords and location information, it is possible to create complex and efficient queries and improve relevance of the search results. Several NLU platforms were considered during the research. Almost all platforms provide capabilities for intent and entity recognition. Dialogflow and wit.ai can be used free of charge while others are for commercial use only. [6]

The Search Component provides search functionalities and is based on Lucene Core. Lucene Core is part of Apache Lucene, which is an open-source full-text search library. Apache Lucene can be used for creating search engines [14]. The library is based on an indexing and searching concept. The index of the search component consists of documents. Each document represents a mapping of a JSON object. Each key-value pair of the JSON object is stored in a text type field. The searching process begins with the query generation. Each query is created based on the information provided by NLP and NLU components. The search component implements methods for generation and update of different query types (e.g. Boolean, Term, Phrase, Range, Wildcard) and for running them on a single or multiple text fields. For example, a location query generated by a search component is a term query and is executed on the country document field. The search method executes queries on the defined index and the retrieve method retrieves them in form of documents. The search results are listed based on document score. To avoid large amounts of results and to i-prove relevance, a threshold had to be defined. Each search result is maximal three hundred characters long and includes a link to the page from where it was retrieved. An evaluation of the Solr search server was also considered during the research. Solr is built on top of Lucene and provides REST-like API for querying and retrieving of documents [15]. In contrast to Solr which is used for enterprise and content management system, the Lucene Core is suitable for programming prototypes, because it provides full control over internal processes.

The Logical Component communicates with the client side and is responsible for interaction and information flow between the components. It also manages the conversation flow and context, and forwards results to the client. The logical component performs particular actions and sets particular contexts depending on the intent matched on the NLU platform. Five different contexts can be activated. They are also grouped in “search” and “upload” contexts. In case of a large amount of search results, the logic component activates one of the “search” contexts (continent, country or category) and requests additional input from the user. The context stays active until the results are forwarded to the client. Since the chatbot also supports the user while uploading multimedia content, the logical component provides methods for acquiring and verification of the entered information. In this case one of the “up-load” contexts is activated. If the requested information is entered and its verification is successful, the information is uploaded to the website.

4. *Testing the Chatbot Prototype*

In order to test the chatbot, several example questions have been defined as can be seen in Table 1. The aim is to show how the chatbot behaves when it receives questions that include different information.

Question	Text
Q1	Can you provide some information about Nigeria?
Q2	Give me some information about energy in India
Q3	How many airports does Croatia have?
Q4	I need information about population
Q5	What are the most common natural hazards?
Q6	Can you provide information about energy?
Q7	I would like to upload a video

Table 1. Example questions

Since the knowledge base consists of geography information, the main focus was on location tags within a question. If the location is found and the number of search results is within a defined range, the chatbot displays the search results as illustrated in Figure 5. The location information is also present in question 1 and question 2. Because of the large number of results, the chatbot would pose clarification questions. In this way it would gather additional information and perform the search again. The procedure is repeated until the number of results is within the defined range.

Fig. 5. Search results for Q3

Questions 4, 5 and 6 do not provide any information about the location. The chatbot would perform a search and in case of a large number of results, require a location information (country name). Once the chatbot receives a location tag, it would either proceed with follow up questions or display the search results. Figure 6 shows the conversation flow for question 5.

The NER tool of the used NLP library showed shortcomings. Some of the continents were recognized as a country or as a city. This caused the chatbot to fail to answer questions containing the misinterpreted information.

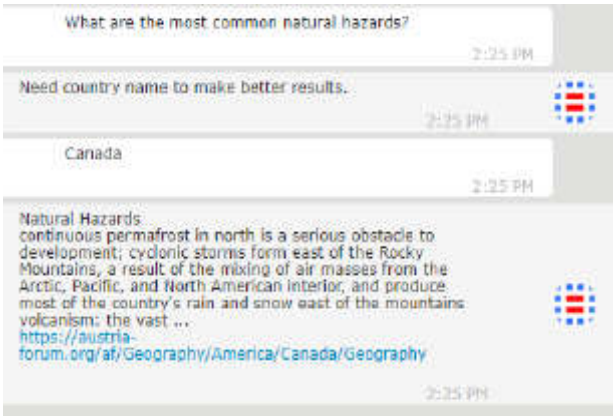

Fig. 6. Search results for Q5

As already mentioned, the chatbot is able to support users when uploading pictures, video or audio clips. This scenario occurs if a user poses questions similar to question 7. The chatbot would activate upload context and gather information from user, verify it and in case of successful verification upload the information to the website.

Since the chatbot is a closed domain chatbot, it does not provide answers to every user question. The knowledge base determines the intelligence of the chatbot. If a user searches for information which is not related to geography and does not exist in the knowledge base, the chatbot will answer with one of the pre-defined answers. The chatbot does not generate new answers but retrieves information and makes it available to users.

In addition to the search agent that was created, the built-in Small Talk agent was activated on Dialogflow. The Small Talk agent is able to match Small Talk intents and extends the number of user inputs that can be handled. This capability contributes to the improvement of user experience.

In contrast to search engines, the chatbot accepts queries in form of full sentences in natural language as well as keywords. In most cases the choice of the question form affects the search results. The search results contain a chunk of text and a link to the page containing the relevant information. The number of search results to be displayed, as well as the content length of each result, can be configured.

5. Conclusion

The goal of this work was to develop a chatbot standalone application that can be used as an information retrieval tool in a geography domain. The chatbot should be used for information search, as well for upload of information.

At the beginning of this paper, its context and the problem of the relevance were introduced. Definitions of chatbots and drivers behind increased interest in development were discussed. Types and areas of application were mentioned with the focus on information retrieval field.

The knowledge domain represents the brain of chatbots. It was shown how to design and structure a semi-structured data. In the future this step should be considered to create a relational database and use the chatbot as a natural language interface. The setting up of an agent on an NLU platform was described.

The architecture of the chatbot system, its components and libraries used were discussed. It was shown how a natural language understanding component in an information retrieval chatbot system can enable the generation of qualitative and complex queries

and in this way improve the relevance of search results.

At the end of this work, the chatbot prototype was tested on several questions. The results showed that the chatbot provides satisfactory answers. The chatbot has potential as an information retrieval tool and could be used as an alternative to an integrated search engine in a closed domain.

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Insights to the State-of-the-Art PDF Extraction Techniques

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Abstract: ***Digitized documents have become the omnipresent medium of information. A plethora of scholarly documents on the web is excessively being increased. Various digital libraries such as Google scholar, Citeseer, MAS etc. store this plethora in different formats. Most of the scientific literature is stored in Portal Document Format (PDF). PDF documents hold a complex structure due to which their comprehension and extraction of useful information from them is a challenging task. In this regard, research community has been proposing different rule based and machine learning based techniques in the past several years. We believe that accurate and efficient information extraction form the PDF files is an important issue as major portion of scholarly literature is stored in PDF. This study presents a rigorous analysis of the contemporary state-of-the-art in PDF data extraction. The contemporary approaches from the window of past few years are recapitulated with the primary objective to assist the scientific community by providing them knowledge about current trend in PDF extraction techniques. The study also presents critical analysis and suggests future dimensions of some of the approaches.***

Index Terms: ***Key Information extraction, Research papers, PDF parser, Regular expression, XML and plain-text formats***

1. INTRODUCTION

For past several years, the paradigm of modern world has been shifted to the digital world in almost all spheres of life. Due to rapid growth of inventions in Science, huge plethora of research documents is produced by the scholarly community. According to [1] quantity of research papers is getting doubled after every five years. Digital libraries such as Google Scholar, Citeseer, Microsoft Academic search (MAS) store this bulk of data in different formats. These libraries contain around 114 million scholarly documents in the form of Portable Document Format (PDF) [2]. This excessive increase has posed a challenge for the scientific community in terms of finding best solutions to extract relevant information from this Big data [2]. Research community has proposed several techniques to extract the information from different formats of digital corpora and remained successful to some extent. However, the issue of extracting desired information from PDF has not been addressed with adequate accuracy. This is due to the lack of proper apprehension of PDF structure [3]. Dating back from the late 90's to date, researchers have proposed various techniques [6–11, 13, 14, 16–22] to extract information available inside PDF documents. Major portion of scientific documents available on the web is in the form of PDF, therefore, researchers must focus on proposing techniques to extract information from those documents in a coherent manner. This study presents a comprehensive literature review of the research conducted in this area and provides a critical overview of all the proposed approaches. The primary objective of this study is to assist the scientific community by providing rigorous analysis of state-of-the-art PDF extraction techniques so that they can evade the hassle of finding the relevant literature and then, have longer time to reach out to the important issue.

Some portion of PDF extraction techniques have focused on extracting data by considering logical sections of research papers. Logical extraction is the identification of the document into the logical sections, such as header, footer, abstract etc. Research community has proposed several techniques to evaluate the logical structure of the PDF. The approach proposed by Ramakrishnan et al. [4] performs layout analysis of the document and converts the PDF document into simple text file by identifying the text blocks. These text blocks are then categorized using a set of rules prepared by detailed analysis of documents. The system provides layout extraction with high precision; however, their system does not include extraction from graphs, tables, citations and figures. Dr. Inventor [5] is another framework to extract the logical structure of the document. It

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converts PDF document into XML format. This conversion from PDF to XML provides feasibility in section identification. PDFX [6] converts PDF document into XML format by generating output in the form of XML. The output XML is generated by performing layout analysis of PDF document, followed by the identification of each extracted layout. The converted XML format contains geometrical features of the sections as well as the sections labelled according to the type of information that the tag contains. D´ejean and Meunier [7] proposed an approach to convert the PDF document into XML format. Their approach converts streams available in the form of PDF to structured XML. Identified heuristic are applied on the streams to logically evaluate the extracted structured XML document. Converting digital documents in the form of XML can help in extracting the information in a coherent manner. Riaz et al. [3] proposed an approach that works by converting PDF document into XML format using PDFX. The identified XML tags are then passed from multiple heuristics to extract the metadata of research documents. This approach was considered best metadata extraction approach among all the approaches presented in Extended Semantic Web Conference (ESWC) [8], securing an f-score of 0.77.

Researchers have proposed various machine learning approaches [16–19, 21] that extract information from PDF documents. GROBID [9] extracts metadata using machine learning approach and then generates a web request to extract the bibliographic information from PDF documents. Another approach CERMINE [10] extracts information from PDF documents in multiple steps. It performs the layout analysis and then classifies the type of metadata. SectLabel [11] performs metadata extraction and content classification using CRF [12], a machine learning approach that performs a probabilistic structure prediction using large set of input features. Klampfl and Kern proposed an unsupervised approach [13] to extract metadata from PDF documents. The approach performs logical structure analysis of a PDF document and extracts information from that logical structure analysis using unsupervised learning.

Hybrid approaches have always been employed by various researchers to extract metadata from PDF files. PDFMEF [14], combines open-source frameworks such as GROBID [9], CERMINE [10], ParsCit [15] to extract the information from a PDF document. Tuarob et al. proposed an approach [16] that identifies the section boundaries using machine learning approach and then labels these identified sections as standard identification (Abstract, Introduction, Background, and Experiment, etc.) using heuristics prepared by analyzing these PDF documents. Sateli and Witte [17] have combined the LOD-based Named Entity Recognition (NER) tool with the rule-based approach to extract information from PDF documents. This approach was considered second best information extraction approach in ESWC [8], by securing an f-score of 0.61.

So far, we have briefly recapitulated the trend of contemporary state-of-the-art in PDF extraction. The following section presents rigorous analysis of existing PDF extraction techniques.

2. Analysis of State-of-Art Techniques

The existing PDF extraction techniques can broadly be categorized into three types: (1) Rule/Heuristic based (2) Machine Learning based and (3) Hybrid approaches.

2.1 Rule Based Approaches

Rule based approaches are based on common patterns identified in the documents after a critical analysis of the dataset. Based on these identified patterns, multiple rules or heuristics are created to extract the information available inside the PDF.

Jahongir and Jumabek [18] extracted metadata from PDF documents. This approach works in three steps (1) Classification of the PDF files, (2) Metadata extraction, and (3) Storing PDF files in the form of XML or JSON. First step performs the classification of the document as either scientific or non-scientific. If the document contains keywords such as ‘Abstract’, ‘Introduction’, ‘Reference’ and ‘Conclusion’ etc. then these documents are termed as scientific documents and are processed further to extract metadata. The second step performs the metadata extraction and outputs the extracted metadata. The textual and font features are extracted using the Apache PDFBox [19]. The identified rules are applied on the extracted text to extract ‘Abstract’, ’Keywords’, ’Body text’, ‘Conclusion’ and ‘References’. The rules proposed by this approach are illustrated in Table 2.1. The final step of their methodology stores the extracted information in the form of XML or JSON. The approach achieved and accuracy of 97.71% for document classification and 96.31% for metadata extraction. Although the approach achieved a very high value of accuracy on the evaluation dataset, the formed rules are not generalized, thus, the results could not be similar for all the data sets.

Riaz et al. [3] proposed a rule-based

approach for extracting information from PDF documents. Their approach works by converting a PDF document into XML and plain text format. Each metadata extraction is performed by the respective metadata unit, and each unit consists of mainly three parts (1) Metadata identifier, (2) Metadata refiner, and (3) Metadata splitter. Metadata identifier identifies the metadata from the XML, followed by the metadata refiner that cleanses the identified text. Metadata splitter splits each extracted metadata and outputs actual extraction information. Firstly, it converts PDF document into XML format using PDFX [6]. PDFX converts the PDF document into the tagged XML. Further processing is performed on that tagged XML to extract the actual metadata and to output metadata information in the form of RDF triples.

The metadata information of author, affiliation and country is extracted by 'Author parts extractor'. This unit finds the title of the PDF document from the converted XML file and extracts the text between the title and 'Abstract' key phrase for further processing. Authors and affiliations are extracted using heuristics. Once these are identified, the country is extracted from the affiliation part using a predefined country list that contains names of all countries in the world. After the extraction of the author and affiliation, the author is affiliated with the respective institution, generating an output that contains the author, the affiliation, and the country. Information regarding figures, tables, supplementary material links, and funding agency is also extracted using the XML format. Regular expressions are developed for extraction of figure and table information using XML tags. Tables are extracted by using "> (Table|TABLE) [A-Za-z0-9\s\.:,\(\)*\%/-]{4,} </caption>" regular expression. The extracted information is then cleaned by removing the extra characters from the extracted text. The figures are extracted using multiple regular expressions developed from the XML format. If one regex does not return any output, then another regex is applied for the extraction of figures. Once figures are extracted, each figure is separated and extra characters that are not part of the figure are removed by the refiner. Supplementary material links are identified by following regular expression "http [A-Za-z0-9\\.#\%,:\/_\-\]*", which afterwards cleans its output. Same as figures, funding agency is also extracted using multiple regular expressions, which are formed by critically analyzing the text of the PDF document in the text viewer tool. Each unit output is passed through the content cleaner phase that removes the extra characters from extracted text and forwards it to the splitter, which outputs the metadata id along with the metadata text. The section identification is performed using both the XML and plain text formats. PDFX tool outputs the section headings as '<h1>' tag. After critically analyzing the sections headings in both plain text and XML formats, multiple heuristics are applied for the extraction of section headings. After the extraction of headings, these headings are separated with their number and passed for further processing. After the completion of extraction phase, they store the metadata in the form of triples using SPARQL. This component consists of two parts: the first part collects all the collected information extracted by using all the extraction units and the second part stores this extracted information in the form of RDF triples. This approach was developed using the training dataset of ESWC [8] consisting of 45 research articles, having different formatting styles and features. This approach was considered as the best performing approach in the ESWC, securing an f-score of 0.77, followed by the approach proposed by Sateli and Witte [17], that will be discussed in later sections.

Riaz et al. approach used PDFX (an open-source tool) [6] for the conversion of PDF document into XML format. PDFX performs the reconstruction of logical structure of the PDF document and identifies each block in terms of title, section, table, references etc. This tool works in two phases: first stage constructs a geometrical model using the content of the article and the second phase identifies the logical structure using the geometrical model generated in step 1. Multiple font features and geometrical features such as orientation, textual context, boundary, and font information are used by this tool for identification of different logical units. The most basic logical separation is performed using font size, whenever font size changes, a new logical unit starts. Furthermore, font frequency graphs are used to separate common text (section text) from the rare text (title, heading text, tables/ figures text etc.). The tool converts PDF documents into small text blocks and merges these small blocks afterwards, using the font and geometrical features. After merging the textual blocks, reading order-based rules are applied to label each logical unit as title, author, email, section, figure, reference, body etc. This approach was tested on Elsevier and PMC dataset, securing an f-score of 0.77 for the extraction of metadata and identification of logical units.

Another approach proposed by Klink and Kieninger [20] also incorporates the textual and physical features of PDF for the extraction of information from PDF documents. The

approach constructs the logical structure of a PDF document and identifies the header, footer, body text, table, and listings. Header section is identified by reading the text from the top of the page until a very large gap than usual is found. In the same manner, footer is identified. Lists (bulleted, numbered or dashed) are identified using the heuristic that the first character will be number, enumeration, dash, bullet or dot. Body text is also identified using the geometrical features such as start of the block, spacing between blocks and change of font features. To identify the tables, authors have used the algorithm proposed in T-Recs [21]. This approach was evaluated on the corpora of University of Washington received by the German Research Center for Artificial Intelligence. This approach achieved precision of 0.98 for 90% documents. However, the approach has proposed only one rule to extract information from PDF. It could further be enhanced by using a set of rules that can make extraction more diverse.

2.2 Machine Learning Approaches

Machine learning based approaches facilitate in terms of making a supervised system through learning different formats and features. Using this learning, the system can extract information from the PDF document in an automated manner. This section presents in-depth analysis of the machine learning approaches.

GROBID [9] is an open source ML library that performs extraction, parsing and reconstruction of a PDF document into a structured text. The system works by extracting the title, author, abstract etc. using the Conditional Random Field algorithm. After identification of the information, the system generates a web request that generates full metadata of the publisher. The approach has achieved an accuracy of 83.2%; however, the results may possibly be accurate only if the title and first author information is identified correctly by the system. This system is now available as an open-source tool and is in process of constant development.

CERMINE [10] is also an open-source ML tool that extracts metadata and content from a PDF document and generates an output in the form of XML or plain text. It performs the layout analysis in which character extraction, page segmentation, and reading order is resolved. Character extraction identifies characters along with their position on the page, whereas page segmentation stores the hierarchical structure of the document content in the form of zones, lines, words and characters. Reading order is used to maintain the right order in which the structure should be read. After layout analysis, content classification is performed in two steps: firstly, initial zone classification is performed which labels each zone as metadata, reference, body or other. After initial zone classification, metadata zone classification is performed that classifies each zone into specific metadata (title, author, affiliation etc.).

Layout analysis is performed in three steps: (1) Character extraction, (2) Page segmentation, and (3) Reading order resolving. Character extractor extracts each individual character from the PDF stream along with their position on the page, width and height. Page segmentation creates a geometric hierarchical structure storing the document's content that results in representation of document as a list of pages, where each page contains a set of zones, each zone containing a set of text lines, each line contains a set of words, and finally each word representing a set of individual characters. In the final step, reading order is resolved to determine the right sequence of the elements, in which they should be read. Resolving reading order helps in zone classification to extract full text of the document in right order.

Content Classification performs the labelling and determines the role of each identified zone. This phase works in two steps, first labelling each zone in one of the four classifications: (1) Metadata, (2) Body, (3) Reference, and (4) Other. After initial zone classification, multiple classifiers such as K-means clustering, CRF, or SVM are applied for metadata and bibliographic extraction. The system achieved F score of 0.95 while classifying zones and F score of 0.775 on metadata extraction.

SectLabel [11] is ML approach that also uses CRF to extract information from a PDF. The system uses 13 different types of metadata to tag extracted information: abstract, categories, general terms, keywords, introduction, background, related work, methodology, evaluation, discussion, conclusions, acknowledgments, and references. The approach works in two steps: logical structure classification and generic section classification. Logical structure classification tags each line as one of the 23 categories proposed by Loung et al. i.e. address, affiliation, author, body text, etc. This classification is identified by features such as location, number, punctuation, and length. The second step performs the identification of the generic sections (Abstract, Methodology, Results etc.) from the PDF document. This approach focuses on finding the type of generic section from the section heading. The generic section information (such as position, first word,

and second words), header information is used by this system. The approach was evaluated on a dataset consisting of 40 research articles. The results yielded an f-score of 0.84 by using the maximum set of font features.

Klampfl and Kern [13] published a study in ESWC, that performs the reconstruction of logical structure and extracts metadata using supervised and unsupervised learning. This approach uses Apache PDFBox [19] to obtain the low-level PDF streams. These streams are then combined using Merge and Splits. Merge performs horizontal and vertical clustering, whereas Split removes the merging of the text across the columns. Using these techniques, characters are merged to form a word. These words are combined to form a line and finally lines are combined to create a complete block. The approach uses supervised learning to extract the information related to header section (Author, Affiliation, Email etc.). Maximum Entropy in combination with Beam Search is used to extract and classify results and to avoid incorrect label sequencing. Key words like 'Table', 'Fig.', 'Figure' etc. were searched below/above the tables and figures to identify the captions. Sections headings were identified by using labelled text blocks in combination with the geometrical features. Multiple heuristics were applied after the extraction of the section heading, to make the section heading identification more accurate. Once all the information is extracted, it is stored in the form of RDF triples. This technique was prepared by using the training dataset provided by ESWC, consisting of 45 papers. The approach achieved an f- score of 0.592.

2.3 Hybrid Approaches

Hybrid approaches work by combination of multiple approaches. These approaches incorporate rule-based approaches with ML approaches, and they also combine several other data warehousing techniques with machine learning or rule-based approaches to extract metadata information.

Sateli and Witte [17] published a study in ESWC, that combines the LOD- based NER tool with rule-based approach to extract metadata information from PDF documents. The approach works by converting a PDF document into textual format and tags each part of each sentence as a part of speech. After tagging, each word is stored in its base format, to remove the likeliness of morphological variations. After performing the syntactic processing, the approach performs semantic processing in iterative phases, adding more and more annotations in each phase. Based on this tagged information from the semantic processing, manually developed rules are applied to extract information from the PDF. Authors' names are extracted by using gazetter, which helps in recognizing common first names and tags them as 'Author'. Affiliation and Country extraction is performed by annotating lines of metadata section (part of research article between title and abstract) using the LOD cloud. Afterwards, the annotated information is passed through a set of rules to extract the affiliation of the research article. Information regarding tables, figures, and section headings is extracted in syntactic phase wherein terms are annotated as the metadata information. If any of this information is not found, then, for tables and figures, a set of trigger words is used, and section headings are checked against gazetter to find conventional research article headings (Introduction, Conclusion, Experiments etc.). This approach was evaluated on the training dataset of ESWC, consisting of 45 research articles, and achieved an f-score of 0.63.

Another hybrid approach proposed by Tuarob et al. recognizes hierarchical sections from the PDF document [16]. The system automatically recognizes section boundaries and standard sections of the research articles. The approach proposes 22 different features that can be used to identify section boundaries. These identified features can mainly be characterized into: (1) Pattern based, (2) Style based, and (3) Structure based. Pattern based features are used for finding standard sections of the PDF document. Style features help in removing lines that are not part of a section, such as tables, figures or captions. The structure features are used to identify the location of the section in the PDF document helping in the identification of the section more accurately. Multiple classifiers like SVM, RIPPER, RF and Naïve Bayes are used to identify section boundaries. A proposed set of rules is applied on the sections, to identify them as Abstract, Introduction, Background, Conclusion, and Acknowledgment. The approach was evaluated on the dataset comprising of over 200 PDF documents, selected from CiteseerX. The approach achieved an accuracy of 92.38% and 96% for section boundary recognition and section identification respectively. However, it focuses on extracting the textual content of the PDF document, ignoring figures, tables, and listings etc.

PDFMEF [7] is an open-source multi-knowledge extraction framework that performs extraction of metadata by incorporating multiple open-source systems. The open source

systems are used for the identification of metadata. GROBID is used for header information (author, email, affiliation etc.), whereas PDF Figure is used for table, figures and algorithm extraction, and ParsCit is used for extracting the information regarding citation. The performance of PDFMEF is based on the underlying open-source software used for the extraction. The f-score of header section is same as the f-score obtained by the GROBID. In the same manner, the accuracy and f-score of extracting figures, tables, algorithm and citation depends on PDFFigure and ParsCit.

4. ANALYSIS

The critical review delineated in the above section states that contemporary PDF data extraction techniques belong to three broad categories: (1) Rule based approaches, (2) Machine learning approaches, and (3) Hybrid approaches. All of these techniques have their merits and demerits. There does not exist any approach that could be deemed as generalized and applicable in all the scenarios. The following table concretely recapitulates the existing PDF approaches.

Table 1 Recapitulation of state-of-the-art PDF data extraction techniques

Paper	Approach	Category	Accuracy	Limitation
Ramakrishnan et al. [4]	Performs layout analysis	Rule-based approach		The system does not include extraction from graphs, tables, citations and figures.
Jahongir and Jumabek [18]	Extracts metadata of research papers	Rule-based approach	Achieved accuracy of 0.96	The formed rules are not generalized and approach does not behave similar for different data sets.
Riaz et al. [3]	Extracts metadata of PDF documents	Rule-based approach	F-score of 0.77	The extraction of metadata is dependent on the output generated by PDFX. The approach has been evaluated on a very small data set.
Klink and Kieninger [20]	Extracts metadata of PDF documents using textual and physical features of the PDF		Precision of 0.96	The approach follows only one rule for each information it extracts. There should be more rules for diverse extractions.
GROBID [9]	Extracts metadata using Conditional Random Field Algorithm.	Machine-learning based approach	Accuracy of 83.2%,	The results may possibly be right only if the title and the first author information is correctly identified by the system.
CERMINE [10]	Extracts metadata and content from PDF files using K-means clustering, CRF, and SVM classifiers	Machine-learning based approach	F score of 0.775	Text extraction is dependent on libraries (iText). Headings, tables, and figures have not been extracted.
SectLabel [11]	Performs logical structure classification and generic section classification of PDF files	Machine-learning based approach	F-score of 0.84	The results have been evaluated on a very small data set.
Klamp and Kern [13]	Performs reconstruction of logical structure and extracts metadata using supervised and	Machine-learning based approach	F-score of 0.592.	The data set contains only 45 research articles, which is very small to be used as a training dataset for ML approach.

	unsupervised learning.			
Sateli and Witte [17]	Combines the LOD-based NER tool with rule-based approach	Hybrid approach	F-score of 0.63.	The rules crafted in this approach were specific to dataset. The size of dataset to develop technique was also small.
Tuarob et al. [16]	The approach uses SVM, RIPPER, RF and NaiveBayes classifiers and Pattern based, Style based, and Structure based features to extract PDF data	Hybrid approach	Accuracy of 92.38%	The approach only focuses on extracting the textual content of the PDF document, and ignores figures, tables, and listings etc.

Most of the rule-based approaches convert PDF document into the XML or plain text format. Applying rules on the converted XML or plain text document is much easier than on the PDF itself. Although the development of rules/ heuristics become much easier, most of the tools that convert PDF into XML format or plain text format, do not fully support all the characters and information gets removed from the converted text, which results in incorrect extraction of the information. Another problem with the rule-based approaches is that, they are not generalized and perform well only on the data set for which the rules have been designed. Moreover, the preparation of rules/ heuristics is also a challenging task and involves cognitive process. As the dataset becomes large, the rules to extract the information becomes more complex and requires more effort to identify different formats to cater all the format in the rules.

Machine learning PDF extraction approaches are more dependent on the obtained feature set from the dataset and a large dataset. Large tagged datasets help in training the system more effectively and extracts the information more accurately. With more training data, the model built by the ML system becomes more effective and accurate. The second challenging task in ML approach is features extraction. The feature extraction methodology must provide correct feature description, as features are main building block in ML approaches to extract and identify the information.

Hybrid approaches incorporate multiple approaches and provide a solution to identify the logical sections or metadata of the PDF document. The problem with the hybrid approaches is that they inherit problems from their parent approaches. Generally, these approaches require a large tagged dataset to train the model more effectively. Also, the feature extractor needs to extract the feature with high precision so that the model could be trained effectively. The required rules are more generalized and complex to create. With the large tagged dataset, the created rules are more complex and demand more critical analysis of the PDF documents.

5. CONCLUSION

In this study, we have presented an in-depth review of existing PDF data extraction techniques. Most of the scholarly literature on the web is stored in the form of PDF files. However, PDF has a more complex structure than other formats. Due to lack of proper understating about the PDF structure, PDF data extraction systems fail to extract information in a cohesive manner. Researchers have proposed various techniques to extract data from PDF files. These techniques are broadly categorized into three categories: (1) Rule-based approaches, (2) Machine learning based approaches, and (3) hybrid approaches. In rule-based approaches, different rules are crafted according to data sets. These rules are then used to extract metadata or content of documents. Similarly, in machine learning PDF extraction approaches, features are formed and supervised and unsupervised learning is applied on them to extract data. Hybrid approaches are combination of rule-based and machine learning based approaches. The analysis revealed that there does not exist any approach that could be deemed as an optimal for all the scenarios. Most of them depend on certain aspects due to which they fail to maintain similar behavior in different scenarios.

For instance, rule-based approaches perform well only for those data sets according to which the rules are formed. Similarly, other categories also have their own limitations and parameters to perform well. In future, scientific community should focus on proposing such PDF data extraction system that rarely depends on features and is generalized enough to maintain similar patterns for different scenarios and data sets.

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Experiences Based on a Major Information Server

Delilovic, Namik; Ebner, Martin; Maurer, Hermann; and Zaka, Bilal

Abstract: ***In this paper we describe lessons we have learnt from building up a webserver with reliable information over a period of ten years. We show how we have tried to overcome often encountered weaknesses and thus encourage the community to follow our suggestions. We also point out that much research and development work remains to be carried out.***

Index Terms: Intelligent Web server; digital library; flexibility in Web servers; Austria-Forum

1. INTRODUCTION

A team involving the authors has been involved in developing a substantial "quality-controlled information server" called Austria-Forum [1], [2], [8], [33] concerning information of interest to Austrians since 2009. The aim of this paper is to correct a misunderstanding: Despite a large number of research results and recommendations for practical use, austria-forum.org, has been misunderstood by many as just "another collection of partially interesting digital information".

This is a serious mistake that needs to be corrected. Of course, the server is offering interesting information on a huge variety of topics, and has gained some respect for this. But the collection of this material has a second reason: Large quantities of information and users are needed to conduct research on how to handle huge amounts of data and users. One approach is to study how to represent reliable information and how to make access to it useful and easy for users. Another one is how to let users discuss important questions. A third one is the problem how to make sure that the material is not just attractive to one age group but to young and old, from school student to persons already having left active life for some time. And a fourth and may be most important in our times: to make sure it allows to differentiate between fake news and real news, between half-truth and objective reality. Much substantial research in those areas seems to have sometimes gone unnoticed. It is the aim of this paper to report on some of the research and development achievements that are influencing the Web, and are needed so that the Web is not just a new way into chaos [7].

2. NUMBERS

The Austria-Forum has some 3 million different (mainly German speaking) users at the time of writing (October 2019), over 1.1 million media objects and close to six million page views per year. It has been successful in showing how to improve critical areas of Web presentations and is attempting to be a kind of role-model for similar attempts by further research and development. Here is an overview of the structure of the rest of the paper:

Section 3: How to avoid the presentation of fake information by using a repository of carefully documented reliable information.

Section 4: What is the role of digitized books?

Section 5: How can one assure meaningful answers from search-engines.

Section 6: How can the software help to provide serious communication between well-defined groups and avoid outpouring of trivialities and fake information as is typical for some social media?

Section 7: How to fight fake news.

Section 8: How to reach all age groups.

Section 9: Conclusion.

All ideas and developments presented in the sections that follow are by-products of research and development of a group supported by a number of universities and sponsors. The development is supported by numerous institutions from within Austria and other countries and a board of some 200 honorary editors and researchers.

Disclaimer: Many of the results have been published in research papers, theses, keynote presentations and the like before. We cannot

discuss all issues involved and are leaving some to be studied in detail using the references provided.

3. Quality Control of Contributions in Austria-Forum

One important way to assure high quality is to make sure that contributions (that are in searches presented, are written by well-known persons, usually with a CV showing their competence. This is also much supported by big efforts like [33].

Users can register (even with an arbitrary pen-name) in a way so that only the system knows the E-Mail address, but still they can contact authors without revealing their identity or E-Mail. The system allows authors to answer, without needing to know the identity of the user who contacted them.

There is a second alternative to provide feedback: Each Web-page in Austria-Forum has a green “feed-back button” [13] that allows to send, without any registration, messages to the administrator, who can act on them, including forwarding them to one of the editors, if this seems appropriate.

These two facts, i.e. that authors commit themselves to what they write rather than to hide in an anonymous group and that two ways of communication for questions, comments etc. are provided, assure a much higher standard of contributions than it is found in anonymous systems where users have no easy way to react and do not know in which direction an author or author collective is trying to color information according to own beliefs, as is sometimes argued about Wikipedia [34}. A second argument that reduces the value of Wikipedia is the fact that different language versions present in quite a few cases very opposing views.

However, in addition to above, Austria-Forum provides another important way to assure quality: It contains thousands of online readable digitized books [11], [13]. Links from any Web-page to any point in a book (and conversely, and from a book page also to another book page) are possible. Hence, an author writing about some matter can make a link to a section of a book dealing with that matter, thus adding to his credibility the credibility of the author and publisher of the linked book. Even if authors (or some member of the Austria-Forum team) have not made links to some book sections (a process to be supported by providing suggestions for links automatically) users can consult books available in Austria-Forum to check issues themselves.

4. What is the Role of Digitized Books in Austria-Forum

As mentioned in the previous section books can be used by linking from a contribution to a relevant spot in a book, or users can check up on statements made on some Web-pages using the books provided.

Since almost all books are full-text searchable, this is often easy. Note that books are readable online (but usually not downloadable). Due to the fact that links from Web-pages lead users to “stumble” across books (of which they might not even have been aware of) many publishers see the incorporation of their books into the digitized library of Austria-Forum not as a competition to selling the books in print or as e-Books, but rather as showing the existence of the books to the public.

Digitized books in Austria-Forum offer much more than usual collection of digitized books, or individual e-Books, or books on Kindle and such. Usually, digitized libraries offer books in “complete isolation”, i.e. neither with links from the Web to a spot in a book, nor supporting a section of a book by e.g. providing additional pictures, or linking to audio or video-clips, or even to some interactive material, potentially turning the book even into an E-Learning system. Even more is true: with new tools, it is intended to link sections of different books (and material on the Web) dealing with similar topics together on demand, thus allowing users to look at a topic in various sources and from various points of view easily, rather than having to laboriously search in all kinds of collections for relevant contributions.

In addition, a new generation of digitized books we are developing is almost ready: It will be compatible with the International Image Interoperability Framework™ (IIIF) [30]. This is expected by most major libraries since it offers many additional features as described in [5].

5. How Can One Assure Meaningful Answers from Search-Engines

There are three different important issues to deal with:

(a) How one can easily find what one wants
(b) How answers are to be interpreted

(c) How one can assure that answers obtained are correct

Concerning aspect (a), search-engines have evolved quite a bit over the last years. If ten years ago you entered “Enzian” (the German word for gentian, a flower often associated with the mountains in Europe) into any good search engine you got a long list of the many types of the flower Enzian, but also the Schnaps (brandy) called Enzian, the rocket Enzian built during world War II and possibly all kinds of “Lederhosen” or hotels or restaurants using the word to advertise that they are close to alpine traditions.

We tried to avoid such a multitude of answers by structuring Austria-Forum into “categories” and “subcategories”. Thus, when you look at the entry page of Austria-Forum and you are interested in the flower Enzian, you probably should not immediately use the search function provided, but first choose the category “Nature” and then the subcategory “Flora”, to narrow the scope of your search. This idea of narrowing the scope of search was picked up in various ways by other systems. In Wikipedia typing a word that can mean more than one object results in showing you alternatives from which you then choose. Google eventually ended up with two parallel approaches: either you can enter a full query sentence describing in some detail what you are looking for or you will get a few hits, but then a set of categories. When you e.g. search for London, you get, in addition to some pictures and links a list of suggestions:

Searches related to London

London **city**
London **uk**
London **attractions**
London **wiki**
London **population**
London **map**
greater London
London **facts**

It is not clear how queries will develop. Some believe that text/language understanding will get good enough to allow very complex queries. We tend to believe that a multi-step process might be better in the end. Typically, the query “London” might result in a few obvious hits (Google-like), then presenting alternatives, after you choose further alternatives, and so on, until the system has determined in a dialogue with you what you are really interested in. Much information on this can be found in [14] and [17].

It is worth mentioning that the categories we use have still another reason: Material in different categories may well come from different sources. The entries in “Biographies” are much based on the huge collection of biographies the Austrian Academy of Science [31] is offering, yet those biographies are very technical and not suitable for the general public for which the Austria-Forum is intended. The category “culture” (Kultur) is really a collection of various special topic encyclopedias compiled under the supervision of one of the editors, the category “geography“ is based on reliable data from different e.g. UN servers, etc. The category “pictures” (Bilder) forced us to merge a number of reliable data-bases. Since title and metadata may differ for the same picture, and the pictures themselves may be a bit distorted, this is not a trivial effort [3), [16]. Encouraged by chatbots and “automatic reporting”, we have also applied this to some extent to geography [15] by using interactive approaches and producing graphs on demand [32].

Aspect (b), how answers are to be interpreted, is often not really understood. However, consider a query like “Number of Nobel Prize winners in the UK”. Most search engines will give you a number, but leave you at a loss, since you don’t know: Is this the number of Nobel Prize winners born in the UK? Or is it the number of Nobel Prize winners currently living in the UK. Or is it the number of Nobel Prize winners who got the Nobel Prize for research they did in the UK, etc. We believe that most search engines ignore the fact that answers without the definition on what the answers are based on, are fairly useless. We have tried always to provide this information in Austria-Forum, particularly in our interactive section on geographic information.

Aspect (c), how does one know if an answer obtained is correct, is clearly very important but also quite hard to answer. After all, more than one well-founded opinion may exist concerning a topic. Thus, in general, the best one can do is to offer a set of answers as explained at the end of Section 4. However, if answers are numbers, one can try to do better. We have checked certain geographic facts in Austria-Forum by using a number of data-bases: if all give the same value: fine. If they differ, the best we can do is to show the difference and point to the sources the numbers come from. So, if you want to know the area of France, we cannot tell you exactly, but we just tell you this:

Factbook: 643801
DBpedia: 674843
Geoname: 547030

Infoplease: 547030
Britannica: 543965
Wolfram: 551500

Here is an attempted explanation for the differences**:** For France, Britannica gives the smallest area. This agrees exactly with the area in the largest German Encyclopedia Brockhaus (2014): It follows the French Land register data that excludes lakes, ponds and glaciers larger than 1 km² and the estuaries of rivers. (This is, by the way, very much in contrast to how the figures are arrived e.g. for Finland that not only includes freshwater lakes like many databases do, but also ocean channels!). The situation of France is particularly complicated also due to overseas departments (by law, genuine parts of France). But should their area be counted? Or how about still more subtle cases like New Caledonia or French Polynesia, with special agreements with France? Or the French Antarctic section that is claimed by France but never accepted in the Antarctic treaty?

Or, not so relevant for France but very much for low lying islands, do you measure the size at low tide or high tide? How about political contentious areas: is the Crimean Peninsula now part of Russia or Ukraine?

What we have briefly mentioned concerning the area of countries applies to many other facts, be it the population of some city, the number of mountains in a country, etc. Some more on this is found in [14].

The idea and results in this section show very clearly that much of further research will be required to solve most issues satisfactorily, but we are proud to say that we have successfully begun to tackle some of them.

6. The Role of the Underlying Server and Communication Facilities

Section 5 has made it clear that search facilities on large servers or sets of servers still need much improvement. This certainly includes Austria-Forum; yet we want to mention a number of issues that we have pursued or are pursuing.

The fact that our information is structured in categories, subcategories etc. makes searching a bit easier, particularly because we allow categories to overlap. Thus, e.g. essays on mobility can also be found under traffic, but only one physical copy exists.

We allow full-text search in each (sub) category: This is essential, since a full-text search over the whole server is unrealistic. The full-text search for digitized books is restricted to one book, but a feature to dynamically define a set of books for full-text search is in preparation.

In a contribution, linking to others is often desirable. Yet linking a word to some other page, just on the basis of the fact that an entry exists for that word, yields a multitude of links on every page, destroying the appearance and readability. We have tried to tackle this problem in a number of ways: A link for a word is only created when the destination is more than a definition of that word; often, a link to one entry does not make sense, hence we have collected contributions into “topics” (“Themen”), as a first try of collecting all relevant contributions together as described at the end of Section 4, and we can link to such collections.

For user-friendliness we allow to initiate a search in Austria-Forum for a word by just double-clicking at it.

Searches (if not full-text) are carried out on the basis of the URL of the contribution, its title, its major headings and associated meta-data. Meta-data, at the moment, is mainly compiled manually and non-structured, what is a serious problem whose solution we have been working on: basically, for each Web-page, meta-data based on textual analysis should be generated and added, or at least proposed for addition. The addition of metadata/keywords for pages of digitized books is planned. This will allow additional search facilities within books and it will also make it easier to find books dealing with a topic of interest.

As has been explained before, registered users can contact authors of contributions. They can also add comments visible to the public to each contribution: Such comments are always verified by the administrative team of Austria-Forum to avoid misuse, but are also a simple tool for an online discussion that we will extend to more sophisticated discussion facilities, often only for well-defined user-groups in [5].

There are other aspects of communication among users and, also, between users and the administration. For this, it is crucial that the identity of all contributors is assured. An aspect of the reliability as addressed in [14].

It is remarkable that as early as 2007 the question was raised whether the Web / Internet,

which are taking over more and more of our cognitive work, are not making us stupid, see [10]. In [4]. A reasonably positive answer is given, yet if one looks at [7], a contribution written by one of the Internet pioneers, it appears that developments have to be observed carefully.

There is one aspect that has not received the attention it deserves. A link in a document is like a “goto” in a programming language, leading to a new place without informing if and when to return to the place where one came from. Already in 1987 this problem was discussed [18]: Ted Nelson suggested “transclusions” rather than links (in programming terminology procedure calls rather than gotos) since he and others [19] tried to convince the community to not use gotos, i.e. links, but few took up the idea [6]: In Austria-Forum a tool we call “InsertPage” does do, however, most of what is expected.

7. How to Fight Fake News and Statements that are Half True.

The comprehensive report [12] has at the beginning a statement that describes the situation very well. It essentially says that we are in danger of developing from a rational (fact) based society into an emotion (feeling) based society simply because one cannot trust facts found on the web. For every statement one can find counter arguments, sometimes solid ones, sometimes on purpose subtly wrong statements, motivated by either political or economic interests.

Hence [12] recommends to have servers in every language with reliable information, one of the attempts of Austria-Forum, but also an attempt by others. Together with the team of the Great Norwegian Encyclopedia [33] the Directorate-General for Parliamentary Research Services of the EU parliament organized a meeting of representatives of all countries involved in building such reliable servers in Brussels Oct. 9-11. The exchange of information between a total of 17 such efforts proved very valuable. It made clear that closer collaboration will be essential to cover all relevant topics. Notice that there are two kinds of major topics of concern to all beyond the usually expected information of mainly national interest.

One set are important developments from energy generation to mobility, from climate change to protecting the environment, just to mention some examples. It is really essential that if one e.g. wants to find out “what is the future of hydrogen energy” (in general or for mobility), one can find a reliable contribution on this topic. This clearly applies to a large variety of topics. It is our feeling that this can only be handled by having groups of experts for specific topics assigned to some country, the outcome translated into all languages (probably semi-automatically with some polishing afterwards).

Another set is information on political decisions on a national or European level. It is unacceptable, as it happens today, that after some (parliamentary) decision subtly modified versions (by sloppiness or on purpose) are distributed over social networks, influencing many receivers without them being even aware that they are manipulated. We believe the proper way to do this is to set up a discussion forum for each such topic, let everyone voice their opinion, but extract from the minutes of the meetings the exact decision that was taken, and if the vote was not anonymous maybe even showing who voted in which direction. In the soon to be released software [5] this facility will be available.

8: How to Reach all Age Groups

Running servers with reliable information is important for all age groups. Yet many servers tend, by the large amount of textual material, or by their design, to appeal more to one age group than to another. It has to be accepted, like it or not, that reading long coherent pieces of texts or full books is done significantly less by younger generations that grew up with smart phones and information from SMS, from social media, from YouTube, etc. Thus, servers will have to be designed to appeal not just to one age group, but to all, i.e. incorporating more pictures, clips and less text in some version and more traditional ways of information in others. Or to put it more generally: whether servers or digital libraries, new developments of IT technology and their effects have to be taken care of.

Encouraging active participation in discussions, even competition (e.g. on the level of schools or classes), maybe quizzes with even some small rewards, or interactive experiments that can be carried out, will appeal to some, may even turn the traditional information server into an instrument supporting learning [9], [20].

9. CONCLUSION

We have tried to argue in this paper that a general knowledge server, offering high quality information, has to support a number of ways to assure such quality; one of the most important ones is to add digitized books with very flexible ways of linking them to other material and to provide functions for feedback and potentially moderated discussion groups.

It should also incorporate different ways of accessing material to make it attractive to more than one age groups and replace the paradigm of only retrieving static web pages by accessing data in such a way that reports, as the user desires, are generated dynamically. We have implemented much of this in Austria-Forum (1] as a prototype and are about to roll out an advanced version (particularly concerning digitized books).

We believe that such a server is not just of interest for the public in general and a valuable tool for teaching and learning, but can also help much in revealing fake news as such and give fair presentations of all the many global problems facing mankind, hopefully in various modes corresponding to different groups of users.

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Investigating Interaction Activities in Digital Libraries: The Networked Interactive Digital Books Project

Zaka, Bilal; Maurer, Hermann; and Delilovic, Namik

Abstract: ***The increase in digitization of conventional books and other forms of print media suggests that digital or e-books are not a passing phenomenon. Present day digital library systems may have transformed the conventional processes into digital environment, however little development work has been done for the progression of traditional library business model in digital domain. Users of digital books want a more open environment where contents from different sources are made available seamlessly. Interoperability at device level, sharing, and a possibility of a convenient and useful annotation system are also general expectations from the standard user prospective. Publishers also need a system with efficient process workflow for the transformation of contents and its online availability. Besides the interoperability, the security and digital rights management is also a matter of concern for the digital content distributors.***

We started off our efforts by establishing system to present digital books online with a possibility of simple links creation. This system is now being transformed into a modern form of digital library where possibilities of enhanced interactions are made available to its users. In this paper we report on new user interaction scenarios added to the library system.

Index Terms: ***Digital Libraries, Interactive learning contents, e-publishing, Online Books***

1. INTRODUCTION

Digital libraries are information systems that facilitate storing, indexing, organizing, searching, and viewing of digitized information contents. These contents can be in form of books, documents, images and multimedia objects. The overall operation of digital libraries can be very heterogeneous in nature depending on the type of contents in libraries. Several e-publishing platforms or digital library system are available that provide the means of content digitization and their availability online. These systems are mostly built as monolithic applications, capable of performing library related function in digital domain similar to how things are managed in physical libraries. However, much needs to be done in terms of exploiting the true potentials of digitized media [1]. The digital libraries can add much value to how contents are presented and consumed by its users. Since modern digital libraries can now support processing of different types of media covering numerous subject domains, we can easily have a very large system user community ranging from content publishers, teachers, students, and professionals. A digital library can be seen as a meeting point for people having different background. It is important that a library system provide good means of communications among its users and give opportunities to add value to digitized information contents of system [2]. A similar effort was started by our research group back in 2009, when a quality-controlled knowledge portal was launched having online book publishing system as its auxiliary module. The Austria Forum knowledge portal and Web-books system now has well over one million information objects and approximately 2500 books available online. These systems were evolved around the research done by our group to introduce the needed interactivity and enhancements in information repositories. The development of Austria Forum and web-Books system gave us good insights into challenges and opportunities of online publishing. Almost a year ago based on our developed understanding of the subject we decided to upgrade our online publishing platform into a more robust, standardized system.

In next paper sections we will discuss the approach adapted for building this advance digital library platform and especially focus on explaining different features added to make this digital library stand apart from its successor and counterpart systems.

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2. NETWORKED INTERACTIVE DIGITAL BOOKS LIBRARY PROJECT

The new form of networked and interactive digital libraries must be capable of using inherent interactive nature of digital media and innovations being done in online world. The next generation library systems may additionally present contents beyond the scope of traditional books and documents [3]. These contents (audios, videos, simulations and infographics etc.) are exponentially increasing in online communities and can significantly add value to book material [4.] It is also desirable to have convenient mapping of annotations for self-use and peer groups. Enrichment of meta-data by user contributions can also help in finding related information and improve information consumption. The core philosophy at work behind development of the new library system was making the system more open, interoperable, and reusable at both application and content level.

To achieve the goal at application level we opted to develop system using a modular service-oriented architecture approach [5]. The system is comprised of components such as management system portal, library access portal, indexing system, imaging and Optical Character Recognition (OCR), and database. The system architecture allows deployment of these components as separate service instances working seamlessly to create a comprehensive digital library system.

For maximum compatibility with common platform infrastructure, the system is developed using modern programming technology capable of deployment on Windows and Linux based OS environments as well as on major web application hosting clouds.

The responsive user interface design allows the system to be used on all major devices and operating systems.

To achieve interoperability and reusability aspect at content level, the information to be used in library is processed, stored, and presented using International Image Interoperability Framework (IIIF) standard [6].

This approach ensures that no additional licensing cost is involved, and system use and its distribution can be managed when required.

3. NID LIBRARY ACCESS AND WORKFLOW

The library system is accessed using two main entry points to the system.

These entry points are:

3.1. The Library Portal

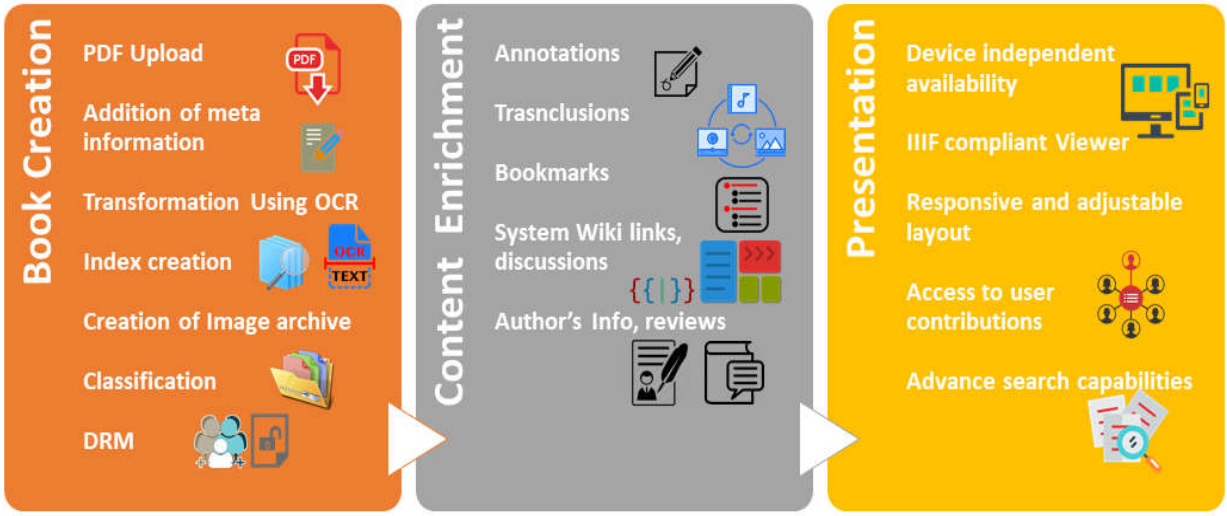
This web interface is mainly meant for common system users. The available books in the system are presented to users organized in categories. The system also displays recently added contents to the system in a prominent way. The user can view books in feature rich book viewer and can make use of advance search functionalities. The major user influx is through library portal, so it is only natural to allow the addition of supplementary contents to library through this channel. More details on type of supplementary information and interactions are part of following sections of this paper.

The second access channel to the system is

3.2. The Management Portal

This is the starting point in creation of base information of library system. Privileged users can setup library environment parameters such as user accounts, documents types, categories, publisher, and digital Right management (access) parameters. The core information objects, i.e. books are also added and processed for use in the system at this portal.

Following figure depicts a simplified workflow in terms of contents creation in NID library system.



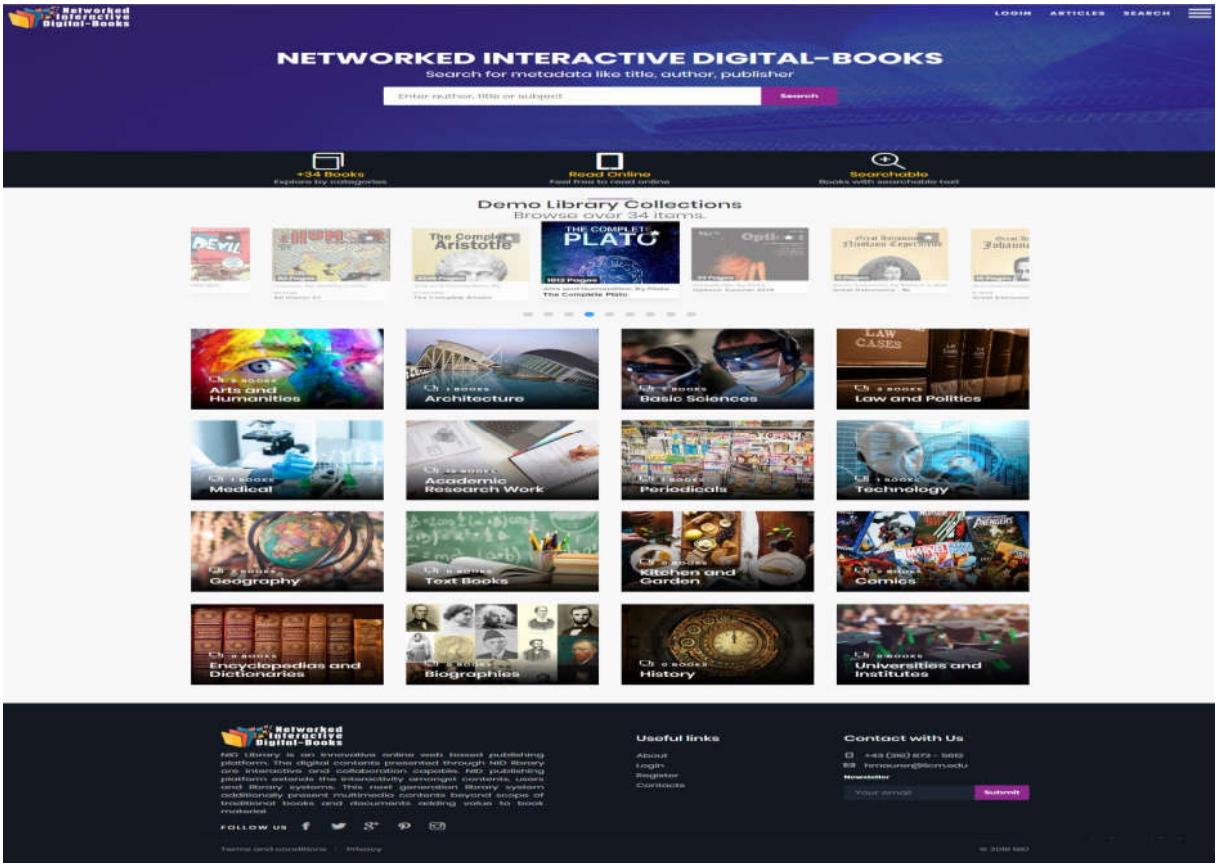
A simple workflow example of NID

4. USER INTERACTIONS IN NID LIBRARY SYSTEM

The NID library system allows different levels of users to access book contents and use its interaction and management features. The NID users include administrative users and editors that can perform tasks related to system administration, content addition, and management. The other types of users are the ones browsing the library and making use of different options to interact with the system and add additional contents and meta information to the library. This paper and section will mainly discuss the interaction activities available to standard system users.

4.1. User Interface and System Access

The first and foremost element of any web-based information system is its User Interface (UI) design; a good UI influences a smooth User Experience (UX) with the system. In order to accommodate a variety of devices and operating system platforms for NID access, we decided to build the system layout based on an adaptive and responsive UI framework. The web interfaces of the library system are built using Bootstrap [7] framework. The layout of NID library is based on grid design that presents text and image contents. The other basic design elements of the system are navigation menus, buttons, form fields with additional features of JavaScript, and Cascading Style Sheets.



System UI / Main library portal

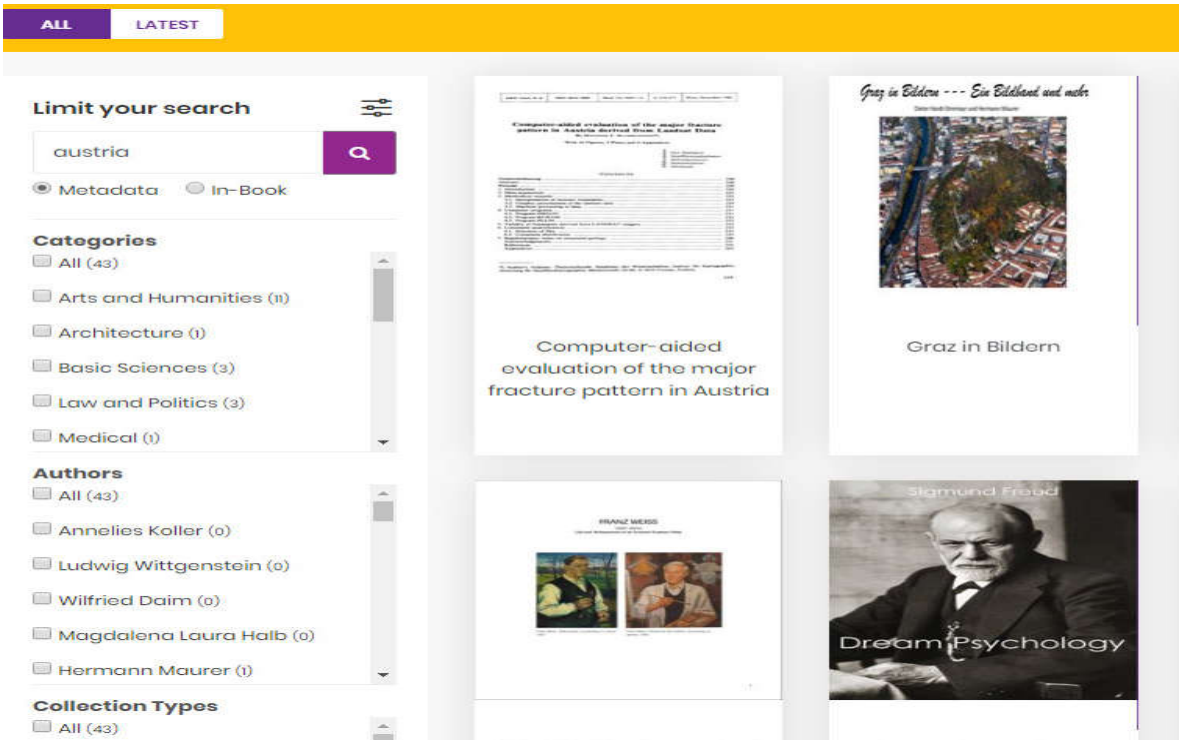
The system can be accessed anonymously; this is the simplest form of system access where any internet user having access to a modern browser on mobile or desktop device can type in the Library Portal URL to view publicly available library contents.

The public availability of library contents is determined using a built-in Digital Rights Management (DRM) system. The rights management is a very critical aspect of online library systems and much attention is needed to incorporate necessary checks for content access and use [8]. The NID DRM feature allows administrative users of library to place a Book/Article of library in either public or restricted access category. There could be different levels of access restriction and it is determined based on registered user access role.

The library contents are presented organized in categories along with a carousel of recently added objects to the library system. The following actions can be performed by users of this category.

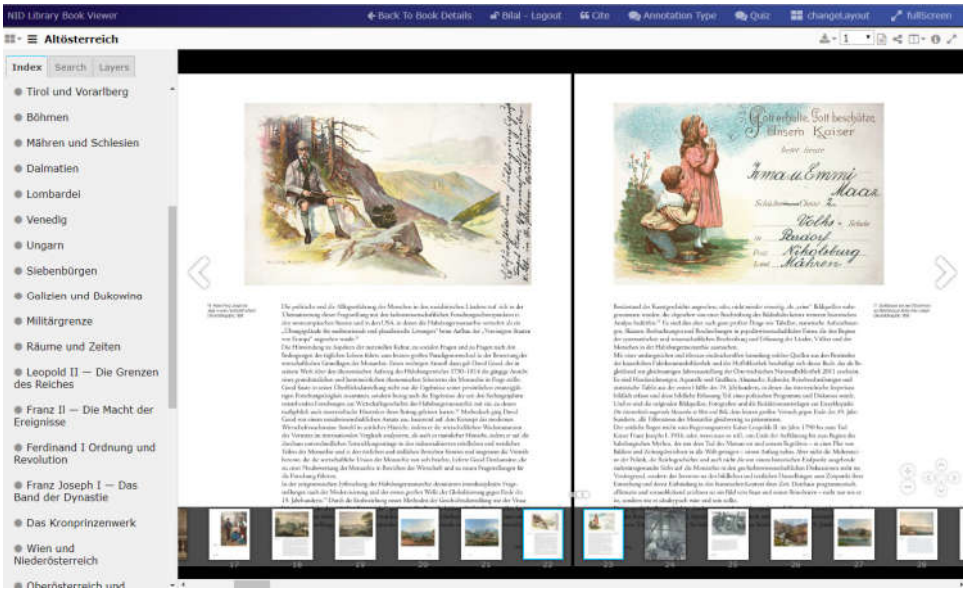
- Browsing books details organized in categories, by clicking on respective category icon and further viewing book details by clicking on selected book cover. User also can view author's biography and reviews associated with selected book at book details page.

- Performing faceted search and filtering operations on library meta data i.e. book titles, keywords, author, category, locations, date etc. Furthermore, on the result page, a user can easily select to perform a more in-depth search on full book text contents. This is done by simply selecting a radio button of "In-Book" search instead of Metadata search default selection. User can perform very comprehensive search by restricting the probing scenario of metadata/Full-text to complete library, selection of certain categories, author's languages, publishers, dates etc.



NID search interface

- The full text search facility made available to NID users supports text extraction from image-based contents as well. The latest version of the most trusted OCR engine Tesseract with the support of 116 languages is incorporated in NID library system. This system component provides the enhanced text indexing facility at the time of book addition to the system. The search query of NID is complemented with operators such as wild cards, AND, OR, and quotes. The NLP preprocessing (stop word removals, stemming) on search index also helps finding the near similar matches.

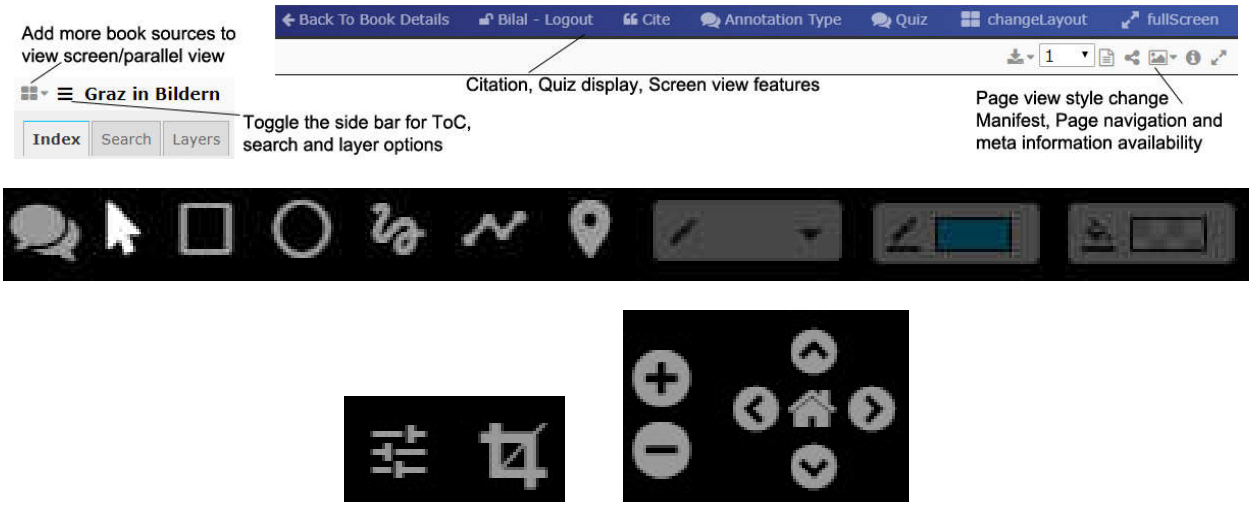


NID IIIF compatible Book viewer

- Users can also access complete book contents in an IIIF standard compliant browser. The NID book viewer is a customized version of Mirador viewer [9] with addition of advance annotations and content highlighting features. In Book view mode, users can perform full text search within a book and easily locate or jump to related content locations.

The NID book viewer offers the following features to all users:

- Presentation of Book contents as Single Page, Two Page Book View, Scroll, and thumbnail View format
- User can enable or disable slider thumbnail at tne bottom to adjust the view area according to the needs
- Within page navigation icons and zoom in/out button are also available to users on screen
- Book page navigation is done using page thumbnails carousel, back and forward arrows on main view panel or through bookmarks and table of contents made available to users as index on a side panel.
- Users can select a viewer layout option and view contents from different books in horizontally or vertically parallel modes. Besides the local library books, loading of parallel view book contents can be done using any IIIF standard complaint source.

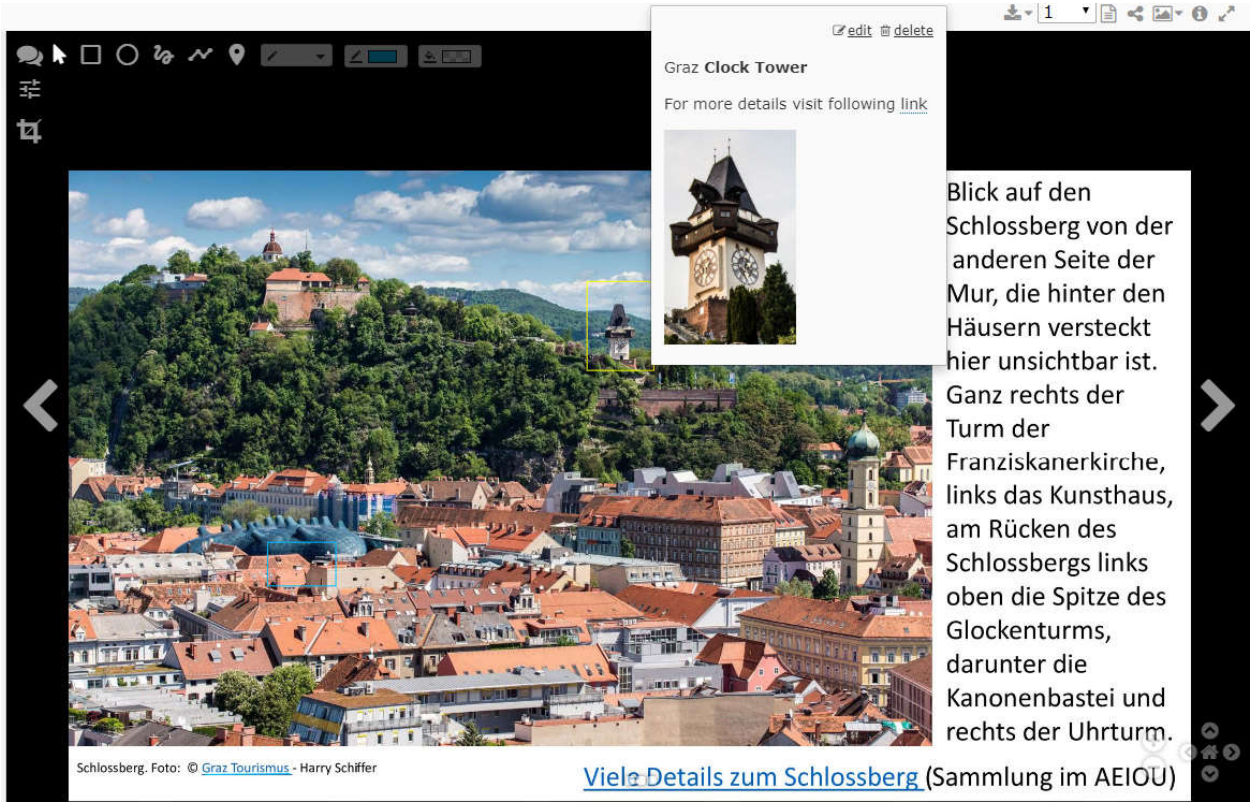


NID viewer navigation and setting menu buttons

- Users can adjust visual aspects of contents such as rotation, brightness, contrast, grey scaling, etc., according to view type requirements.
- User can also activate the share tool, which allows sharing of library contents for transclusions [10] within library and also out of library systems. The feature allows ease of sharing through links to popular social media platforms.
- For reusability and interoperability, the standardized meta information of book contents is made available as downloadable manifest file.
- The public annotations are made available to all users including the ones browsing anonymously. These annotations come in rich media format i.e. formatted text, links, pictures and videos. The annotations layers are mapped on book page as lines, polygons, square, circle, and drop pin shapes in a range of colors. Placement of cursor in respective area shows the annotated information to the user.
- NID system users can also view additional contents placed as WIKI articles. They also have viewing access to related discussions and comments of system articles.

By now we have explained some of the features that are available to NID library users accessing the system anonymously. Once a user registers an account with the system, the following additional interaction features are made available:

- Access to annotation management tooltip, where user can add annotations available to public or only for private and group use. Based on the access level user can edit or delete already added annotation to the system.
- User can select the annotation type being added as Public, Private, or Group specific.
- Users can create within book links, external links to other system books and internet resources.



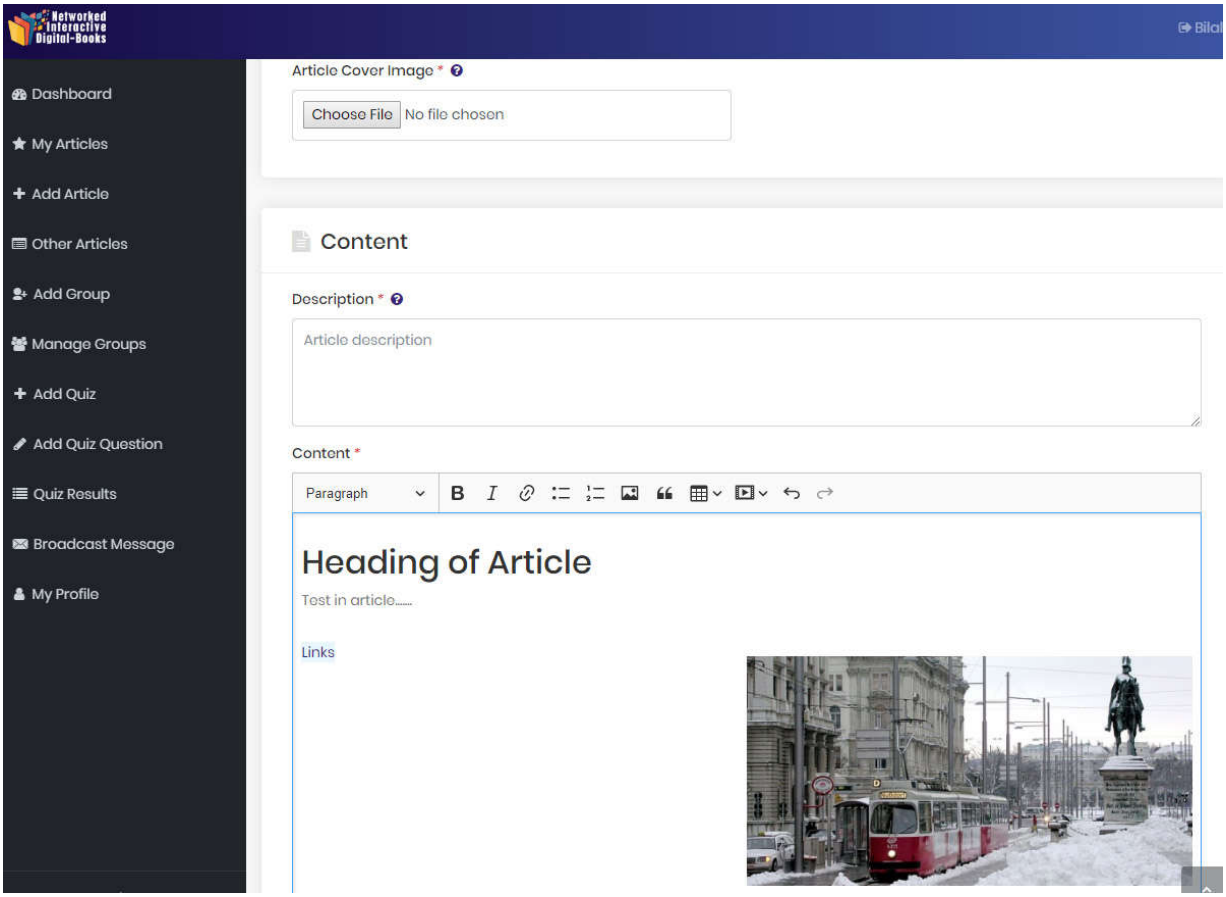
NID simple page annotation view

- Registered users can generate citation in standard referencing style used in academic writings. Currently system supports Book page reference generation in APA, Vancouver, Harvard, Bib Tex, CSL-JSON
- Registered users can also see and respond to Multiple Choice Questions added to different book pages by privileged users or editors. The marked results summary is made available to the users adding MCQs.
- The privileged registered users can also add and edit articles in system using rich media contents. They can upload high resolution images and audio-visual contents to library's local file store. An article can be created using system's WYSIWYG rich text editor allowing ease of formatting.
- Registered users can add book reviews, participate in discussions, and make comments on library articles.

We believe that such a seamless environment, that conveniently presents the digitized books along with a possibility of interactions among users, will in turn enrich original information space with added knowledge layers. All the links, annotations, and comments added to the system may present many useful scenarios where this additional knowledge space is used to determine organized learning objects. The system in a way offers a test bed to data scientists for trying out machine learning algorithms to a variety of structured and unstructured data. The possibility of having a system, where users are creating the additional associated book knowledge and editors endorsing and modifying this additional information for quality, makes conventional e-publishing more interesting.

5. Conclusion and Future Direction of Work

Overall, the NID library project is designed and anticipated to lead to a paradigm shift: So far, we have seen development of complex e-learning environments that are laboriously filled with content; and books in these systems are sometimes just mentioned as background material. With NID it is the other way around: A book represents a certain context within which many interactions, experiments, media etc. are offered in a form suitable for a particular user group. Some of the features incorporated in NID library introduce the much-needed user centric approach of content use and create opportunities of building intellectual relationship between library managers/editors and their readers.



NID editor & registered user feature menu

We see many interesting use cases where ability of book page transclusions through share facility allows creation of customized learning contents. The network and interactivity aspects through use of standardized content presentations and consumption add value in terms of reusability of contents in compatible systems. The extensive inverted indexing and search service API based on web standards also help extending the library meta data beyond system's boundary. Besides the value addition of user interaction that remains the main topic of this paper, we see a lot more potential of this system and our future research will be focused on the use of advance machine learning algorithms to determine learning objects and automated organization of related information entities within a digital book library system.

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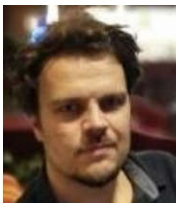

Semantic Partitioning of Triple-Stores

Savnik, Iztok and Nitta, Kiyoshi

Abstract: We propose a partitioning method for Resource Description Framework (RDF) graphs that include a complete conceptual schema in the form of RDF-Schema statements. The proposed graph partitioning method uses the statistics of a graph to compute an abstract graph, called a skeleton graph. The skeleton graph includes schema triples (i.e., edges) from the border in a hierarchy of query types, where the extensions of the schema triples have an appropriate size to serve as the units of distribution. The skeleton graph is clustered using a variant of the k-means clustering algorithm. The distance function that we use for clustering integrates locality-based partitioning with adaptive horizontal partitioning based on the structure of the query space.

Index Terms: Graph databases, triple-stores, data partitioning, graph partitioning.

1. *INTRODUCTION*

Data partitioning to shared-nothing servers is currently the only method that allows for the storage and manipulation of large-scale databases. Various forms of parallel computation can be implemented on a cluster of shared-nothing data servers [3] to speed up the query execution. *Partitioned parallelism* provides parallel execution of a query on an array of servers where the data are distributed using some form of random partitioning, e.g., hash partitioning. *Pipelined and independent parallelisms* can be implemented in query execution systems that are based either on left-deep or bushy trees, respectively.

Data partitioning is closely related to query execution [12]. A query can be posed to a given server or a set of servers only if the addressed data are stored there. Therefore, the design of data partitioning dictates the possibilities for query execution. For example, if the data are randomly distributed to a range of data servers, then a query must be executed on each server in a range, and the results are produced in parallel [1,6,10,13]. On the other hand, if the data is partitioned into locality-based partitions, then a query can be issued solely to those servers that store the addressed data [5].

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Many triple-stores developed over the last decade use locality-based partitioning to speed-up processing of star-shaped queries [5,8,10,16]. The graph partitioning method METIS [9] is often used to compute locality-based partitions. Some newer methods extend the locality-based partitions by replicating the triples from the borders of partitions. The most popular among these methods is N-hop guarantee horizontal partitioning method [8]. Finally, inter-partition query processing can be optimized either using dynamic or static optimization methods [4,8,10, 11,16].

We propose a graph partitioning method that relies on a conceptual schema and statistics of a triple-store. The graph database Yago2 [7], which includes a complete conceptual schema, was used as the experimental environment for developing the proposed method. The method was introduced in [12].

In the first phase of the proposed method, the *skeleton graph* of a triple-store is computed. The skeleton graph is composed of a set of schema triples that represent the types of individual triples. These schema triples have extensions of an appropriate size to serve as the fragments of the distribution. They are selected from the poset of schema triples defined on the basis of the conceptual schema stored in the triple-store by means of the predicates rdfs:domain and rdfs:range. Therefore, the statistics of the schema triples from the partially ordered set needs to be computed to select the schema triples of appropriate size.

In the second phase of the method, the skeleton graph is partitioned into k partitions by using a clustering algorithm. The partitioning is guided by the shape of the function that computes the distance between two edges of the skeleton graph. In the case in which the distance function is defined using statistics, we obtain locality-based partitioning. We also incorporate the following principle into the distance function: the query that addresses a large portion of the triple-store is distributed to numerous partitions, while the query that addresses a small amount of data is directed to a single partition. The partitions of the graph stored in a triple-store are determined by taking the extensions of the schema triples from each particular partition of the skeleton graph.

The rest of this paper is organized as follows. The formalization of the RDF model is described in Section 2. The computation of the triple-store

statistics is presented in Section 3. The proposed graph partitioning method is described in Section 4. Finally, concluding remarks are given in Section 5.

2. Triple Data Model

A formal view of the RDF model is defined to provide a framework for the development of a partitioning method that is based on the semantic information stored in a triple-store. The semantic information is stored in the form of a conceptual schema of a triple-store implemented using the RDF-Schema [15] predicates rdfs:domain, rdfs:-range, rdfs:sub-ClassOf, and rdfs:subPropertyOf.

The RDF graph [14] stored in a triple-store is composed of three types of nodes: class, instance, and predicate nodes. Class nodes must be defined as sub-classes of the top-level class rdfs:Class. Instance nodes are related to one or more class nodes by the predicate rdf:type. The predicates used as the labels of arcs are defined as the instances of the class rdf:Predicate.

As a consequence of the separation between class and instance nodes, we have two types of triples that stand for the arcs of the RDF graph. The schema triples represent the types of instance triples. For example, the schema triple (person,livesIn,city) is a type of instance triple (john,livesIn,tokyo). The node john is an instance of the class node person, and the node tokyo is an instance of the class node city.

The set of all graph nodes are partially ordered using the predicates rdfs:subClassOf, rdfs:sub-PropertyOf, and rdf:type. The generalized relationship among the graph nodes is referred to as the *more-specific/more-general* relationship. The sub-class is more specific than its super-class, and an instance of a class is more specific than its class. Finally, the sub-property is more specific than its super-property.

The partial ordering of graph nodes is extended to triples. A triple is more specific than one that includes components that are more general or equal to those of the more specific triple. The poset of triples is used in the definition of a schema triple interpretation. First, an *ordinary interpretation* of a schema triple includes all its instances, i.e., triples that are composed of instances of the corresponding schema triple components. Second, the *natural interpretation* of a schema triple includes all triples that are more specific than a given schema triple.

3. Statistics of Triple-stores

The computation of the statistics of triple-stores is based on the *triple-store schema* that is composed of a set of schema triples. The schema triples from the schema graph are selected in such a way that they represent the types of queries. The triples that these queries address represent the interpretation of the selected schema triples. The statistics are the counters of all and distinct instances of the schema triples.

The statistics of a triple-store is computed by first deriving the types, i.e., the schema triples, of each particular triple t in the triple-store. The statistics are updated for each computed types of t. Since the number of all possible types of a given t can be huge and the derivation of the hierarchy of possible types implies the disk access for each particular class, the computation time of such an algorithm is unacceptably high. On the other hand, it is straightforward to solely compute the ``stored'' types of a given t, which means that the statistics for the stored schema of a triple-store can be computed efficiently. However, this algorithm does not compute the statistics for the types that are either more specific or more general than the stored types of triples.

We developed an algorithm with which the number of generated types of a given t can be controlled by taking into account only the types of triples that are some levels below or above the stored schema. Thus, the statistics are computed solely for schema triples we consider useful in the estimation of the size of a query result.

4. Semantic Partitioning

Our graph partitioning method is based on a graph schema. Instead of partitioning a complete graph, the schema of the graph is partitioned first, and the partitions of the complete graph are obtained by taking the extensions of the schema graph partitions. The method for partitioning the schema graph incorporates two main ideas.

First, to support efficient processing of star-shaped queries, it is important that the strongly connected components of a graph reside in the same partition. Therefore, the star-shaped queries can be processed on one server without the need for communication with other data servers.

Second, to be able to speed up the queries by means of partitioned parallelism, our method tends to distribute queries addressing a large amount of data to a large number of servers, while queries that address a small portion of a triple store are directed to a single server. Therefore, our graph partitioning method must follow the structure of the query space.

To realize the above two ideas, we first split the complete triple-store into fragments of approximately equal size. We show in the sequel that the query space is defined on the basis of the poset of schema triples. The selected fragments of a triple-store represent the border in the hierarchy of schema triples comprised of schema triples with the extensions of the appropriate size.

The fragments are represented by the schema

triples that serve as the types of triple-patterns. We show that the types define the portion of the triple-store addressed by a triple-pattern. In the case of a type of triple-pattern that is more general than the fragments from the border, it is projected to the schema triples from the border to obtain the schema triples that represent the portion of the triple-store addressed by the particular triple-pattern. In the case that the type of triple-pattern is a schema triple from the border, then only the extension of this schema triple is addressed by a triple-pattern.

The schema triples from the border of the poset are used as the edges of the schema graph. The clustering algorithm uses the schema graph to construct k strongly connected partitions of approximately the same size. The function distance(), which measures the distance between two edges, is based on the strength of the path between the edges, i.e., the size of the query defined by the path.

Let us now present details about the computation of the schema graph as well as the computation of the schema graph partitions.

A. Construction of Skeleton Graph

The definition of the poset of schema triples is based on the predicates rdfs:SubClassOf and rdfs:subPropertyOf. Let us present some examples. The most general schema triple in a triple-store is (owl:Thing,rdf:Property,owl:Thing). All other schema triples are more specific than the most general schema triple. The schema triple (person,livesIn,city) is more general than the schema triple (scientist,livesIn,city) since the triple (scientist,rdfs:subClassOf,person) exists in the triple-store.

The algorithm for constructing the skeleton graph of a triple-store starts with the most general schema triple (owl:Thing,rdf:Property, owl:Thing) and replaces any of the components with more specific components obtained using the predicates rdfs:SubClassOf and rdfs:sub-PropertyOf.

The order of enumeration is important in selecting the actual fragments (edges) of the skeleton graph. First, the S part of the schema triple is specialized. Hence, we first try to find the fragments based on the subject that favors an object-oriented approach to distribution. In the case in which a schema triple cannot be partitioned using the S part, we try to create partitioning based on the O part of the schema triple. If this also fails, then we try partitioning based on the P part.

The algorithm progresses recursively in a depth-first manner until it reaches a schema triple that has the number of instances close to the required number. Then the algorithm backtracks and continues with the next specialization, and so on, until a given schema triple is partitioned using one single component. Therefore, all schema triples that have the extension of an appropriate size are enumerated.

B. Clustering Schema Graph

The edges of the skeleton graph are the schema triples that have the extension of an appropriate size to serve as the units of the distribution. Each edge of the skeleton graph is assigned to a particular partition. The partitions are of approximately the same size. The partitioning function that maps the schema triples from the skeleton graph to partitions is denoted as P.

The partitions of the skeleton graph are constructed by means of a clustering algorithm. The skeleton graph is clustered into k partitions by using the function distance(). As discussed in the introduction to this Section, this function has to incorporate the locality of the skeleton graph edges as well as the possibility of partitioned parallelism.

The locality, i.e., the strength of the connection between two edges, can be defined on the level of the extensions of the triple patterns. The strength of the connection is determined by first computing the shortest path between the edges then computing the size of the join query defined by a path of edges. The strength of the connection between an edge and group of edges is the sum of strengths of connections between all pairs between a given edge and each edge from the group.

To allow partitioned parallelism, we also use, besides the strength of the connections between edges, the concept of sibling edges. Sibling edges have the same parent (more general) edge. In the case in which a group that has the strongest connection with a given edge includes a sibling edge, we take the second best-connected group, etc. Therefore, in the case in which the type of a triple-pattern is mapped to a set of edges from a skeleton graph, the edges are distributed to more servers depending on the actual number of skeleton graph edges.

C. Localization of Schema Triples

The type of triple-pattern tp is t_{tp} such that the interpretation of tp is contained in the interpretation of t_{tp}. After we derive the type of triple-pattern, it is projected to the skeleton graph S_g. The projection of t_{tp} to S_g is called localization of t_{tp}. The localization of a schema triple t_s is implemented as a function that maps t_s to a set of schema triples that are the elements of S_g. The localization function is denoted as L.

The localization is implemented on the same formal basis as the computation of the skeleton graph.

In the case in which the type t_{tp} of tp is more general than all related schema triples from S, then the projection includes all schema triples from S_g that are more specific than t_{tp}. The interpretations of these schema triples include the candidate triples for the query tp.

In the case in which the type t_{tp} of tp is more specific than all related schema triples from S_g, the projection includes *one* of the schema triples from S_g that are more general than t_{tp}. Note that all schema triples from S_g that are more general than t_{tp} also include in their interpretation the interpretation of t_{tp}.

In all other cases, the t_{tp} intervenes in some way with the schema triples from S_g. Let us say that the schema triple from S_g is called t_s. The two possible ways of intervening are as follows. First, one component of t_{tp} is more general than the corresponding component in t_s, and the other two are more specific. Second, two components of t_{tp} are more general than the corresponding components in t_s, and the other one is more specific. In all these cases we can use the intervening schema triples from S_g to represent t_s.

5. *CONCLUSIONS*

We proposed a graph partitioning method, which is based on a graph schema and relies on the simplicity of the triple data model. First, the complete space of the types of queries is organized into a partially ordered set. The hierarchy includes from the most general type to the most specific types of triple-patterns. The uniform structure of the query space provides a convenient tool for the construction of graph partitioning methods. Second, since the structure of triples is uniform regardless of the semantics of the particular triples, they can, in the same way as in key-value systems [2], be freely moved among the data servers.

We argue that the amount of computation required by the proposed method for partitioning a graph database is not high. The computation of graph partitions first requires the construction of a skeleton graph that can be bound by the number of levels above and below the stored schema graph. Second, clustering of the schema graph can be bound reasonably while still obtaining well-defined partitions. Finally, the procedure for the localization of the triples addressed by a triple-pattern needs to process just a few levels of the partially ordered set of schema triples to locate the addressed partitions.

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Traditional and Forthcoming Bridge Design and Implementation:
From Past Experiences to Future Directions

Aroch, R., Asanin, Z., Bobera, D., Bojovic, A., Bojovic, D., Brcic, S., Dakovic, N., Fargier-Gabaldon, L., Furundzic, B., Furundzic, D., Gabrijelcic, P., Gapic, Z., Isailovic, D., Jiponov, A., Jutila, A., Kovrlija, Z., Mandic, R., Markelj, V., Milutinovic, G., Njagulj, V., Peco, D., Ramirez, J., Salom, J., Sreckovic, G., Stipanic, B., Tadic, J., Tosic, N., Ulicevic, M., Velovic, N., and Vuckovic I.

Abstract: ***This article is an opinion article on topics of importance for various aspects of bridge design and implementation (construction, management, aesthetics, social impact, etc.). It is meant to consist of a number of contributions of proverbial nature, short in wording, so the expert opinions of the contributors are easier be to remembered by future researchers or practitioners in the field.***

Index Terms: ***Bridge design, Bridge construction, Bridge aesthetics, Bridge engineering vision***

1. INTRODUCTION

The IPSI Transactions on Internet Research is a journal with a tradition of publishing opinion articles on different aspects of science and engineering. Previous articles of that sort include ten different contributions from Nobel Laureates, as well as the contributions of the highest-reputation experts in fields not covered by Nobel Prize. The rationale behind such an editing policy is to create a database of heritage items of interest for young professionals in generations to follow.

This article is focused on the topic of bridge design and implementation. Therefore, it emphasizes bridge design, construction, and management, but it also includes opinions related to social responsibility, aesthetics, art, and vision. It follows the recommendations of [1] and focuses on creativity behind the expert opinions, as elaborated in [2]. Each contribution is intentionally requested to be short (about 200 words), so that the contributions, over the time to follow, could generate a proverbial value for interested readers.

The contributors were selected from four different sources of interest for this specific mission. Most of them are from Serbia, and many of them were responsible for the most sophisticated bridge designs and constructions, including those bridges that keep various world records in selected categories, now, or in the past. Some of the experts are coming from exYu, EU, US, and Israel, and are strongly correlated with experts from Serbia. Those from the US originate from Purdue University, which, at the time when this article was envisioned, was listed as the World's First for Civil Engineering at the Shanghai List of Top Universities. The contributors from Purdue were responsible for education of some of the junior coauthors of this article (the article includes two basic sections, with contributions from senior experts and from junior experts).

The article is signed jointly by all contributors, using the alphabetical order. However, inside the article, above each contribution, the name of the contributor is spelled precisely, with the affiliated university for academic contributors, and only the place and country of origin for contributors from the practice, since the shared opinions are personal opinions, and not corporate ones.

The distribution of contributions over the four categories in the article was done by the co-editors of the journal, and should be treated as conditional, since most of the contributions do include elements of more than one category, or even all four categories; consequently, the distribution was based on the components that prevail in the contribution (not in the overall professional life of the contributor).

2. SENIOR EXPERIENCES

This section includes experiences of well-established professionals with past and current responsibilities in domains of bridge design, constructions, and engineering in all related aspects, as well as in domains related to social responsibilities, architecture, and art.

2. 1. Design

Aleksandar Bojović, Belgrade, Serbia

Computers and bridge design. The computer will never fail you – it will fulfill even the most meaningless tasks you give to it! The computer cannot increase your creativity, but dealing with the computer in too much detail can, for sure, reduce your creativity significantly!

If the structural solution of the bridge looks good by the engineering judgement, the computer output will surely be positive. Also, if, while proving your structural solution of the bridge, you go deeper into the theory, you will, then, definitely get that the solution is not the '"correct"' one.

Dusko Bobera, Belgrade, Serbia

The beauty of a bridge lies in its simplicity. People build too many borders and for sure not enough bridges. Bridges are the most important engineering structures; nothing is better and more valuable than bridges. A bridge should be not too big, not too small, but just right for its location. It is better to have an ugly but safe bridge, than unsafe but attractive bridge. The elegance and beauty of a bridge can be achieved at a reasonable and sometimes low cost. Using powerful user-friendly software by unexperienced bridge engineers may lead to serious consequences: rubbish in = rubbish out. The beauty of a bridge lies in its simplicity.

Moveable bridge “Port Milena” (Montenegro) is an illustrative example of the above-mentioned principles. It is the first and to this day the only movable bridge in the world built by incremental launching of concrete and steel beam bridge structures together, launched from one side only. Two harmoniously shaped central piers with the shape of a harp and arched intrados of movable steel girder structure form the entrance into the planned marina. The bridge is in harmony with its environment (please check Google for images of the “Port Milena bridge in Montenegro”). In the close future we must use ICT for bridge construction to make “smart” bridges, thus increasing bridge functionality, enhancing durability, all while reducing the bridge maintenance costs.

Jakob Salom, Belgrade, Serbia and Petah Tikva, Israel

Computer engineering aspects. The concept of "smart bridges" is emerging fast. This concept was made possible by advances in computing, on all abstraction levels of modern computing. Possible examples of use cases of computing in bridge design and construction are more than numerous, and not only in the engineering aspects, but also in aspects related to rational economy, social responsibility, and environment aesthetics. Therefore, education of bridge engineers has to include also a strong computing component, as elaborated in the next paragraph. For all areas covered by the next paragraph, the sources were used that strongly impacted this author's views on the related issues.

The more input data is involved in the process, the more effective is the process. However, with more data, the bridge infrastructure computing machinery, based on the classical von Neumann computing paradigm, becomes a bottleneck, so more effective approaches have to be deployed: (A) More parallelism involved, which is a solution based on a carefully applied quantity [3]; (B) More parallelism involved in synergy with proper support technologies, like packaging and powering, etc. [4]; (C) More parallelism in synergy with technology advances, like [5]; (D) Change of the paradigm on the level of basic computing, like moving from the von Neumann paradigm to the paradigms based on observations of Richard Feynman, e.g. [6]; (E) Change of the paradigm on the level of the system software, e.g. [7]; and (F) Change of the paradigm on the level of the application software [8]. In conclusion, a strong symbiosis of civil engineering and computing engineering is a must for the education of the future bridge designers!

Luis B. Fargier-Gabaldon, University of Wisconsin and Purdue University, USA

Issues in bridge science and engineering. Simple load paths, detailing, calculations, and construction are the key ingredients to successful projects. Keep in mind that laws of statics are not open to discussion, they are easy to learn but hard to master, and must be checked at every construction stage preferably with paper and pencil. Remember that concrete behavior is complex, loads are random, supports settle and the quality of construction is often overestimated. Be skeptical of sophisticated analyses unless supported by simple hand calculations.

When proportions and details are selected based on past experiences of the profession and the load path is clear, unambiguous and satisfies statics, one may conclude that further refinements in calculations are futile. Expect the unexpected during construction, the most vulnerable stage. Learn from other's mistakes and have the courage to accept yours in a timely manner and learn from them. Never stick to the first idea; keep looking for improvements even if it requires to start from scratch; avoid working under tight budgets and remember that is valid to say, "I do not know". Lastly, keep in mind that codes lead to suboptimal structures and make sure you know the few safety provisions that have stood the test of time.

Novak Velović, Belgrade, Serbia

Bridges connect past, present, and future. Designing bridges means being in a special relationship with the past, the present, and the future. Taking into account the exploitation age of bridges, it is clear that we are designing for some future times that will come after us. In order to perform these tasks successfully, we use all available, positive experiences, and wisdoms from the past, while respecting today's extremely extensive requirements stated in sets of current standards. As there are no two same obstacles in the world that need to be bridged, that leaves the Designer enough room to express his creativity using the above, thereby giving the structure personal mark.

Today, in the age of the Internet, access to information about existing bridges is made much easier, but I recommend critical approach in it, since there are bridges on which certain problems occurred during the exploitation, which could have been avoided at the design stage already. All the experience from previous bridges, whether they are ours or someone else's, can be classified into the sphere of education that mustn't be interrupted by Designers. This is where we come back to our time, where a step forward can be made by the use of new materials. Speaking about current standards, I advise any Designer to form a list of ultimate and serviceability limit states that the structure must meet at the very beginning of making the design. Designer should check every decision from the aspect of the list, since one unfulfilled condition may mean taking the Project back to the very beginning.

Damir Peco, Belgrade, Serbia

Pre-stressed concrete bridges. Pre-stressed concrete bridges of larger spans built in the second half of the 20th century are characterized by bold structural solutions. The dimensions of the cross-sections and the covering layers are minimal, and both concrete and steel are at the limit of their permissible load capacity. Good design solutions and quality of built-in materials are the main reason why these bridges are still in use today. Designers of these bridges had limited possibilities of calculations from the today's perspective, but yet they have managed to shape structures in global and, also, bridge details with their experience and vision. With the development of modern materials that bridges are made of and the availability of professional programs for the calculation of bridge structures, it seems easy for the designer to provide the load capacity, stability, and usability of the bridge.

I am the designer of the New Beška Bridge over the Danube, next to the Old Beška Bridge built in 1975, as well as of the reconstruction of the Kostova Greda Bridge built in 1968. Today's standards for section dimensioning and quality of materials applied at the New Beška Bridge provide the necessary bearing capacity, usability, and durability of the bridge. However, it is the designer who sets the parameters for the bridge structure calculation. For larger spans, all inadequate design estimates are multiplied, and in the completed bridge, all this reflects on increasing bridge maintenance costs. Therefore, even today, it is necessary for the designer to have a vision of the bridge before the start of the calculation, especially regarding the optimal choice of the structural system.

Rastislav Mandić, University of Belgrade, Serbia

The seismic analysis of cable-stay bridges – a case study. At the end of year 2011 the new cable stayed bridge over the Sava river in Belgrade was completed. The length of the bridge is 967 m. The stay cables are placed in two inclined planes and elastically support the bridge deck with central span of 376 m over the navigation route. Although Belgrade was in the zone of moderate seismicity, the seismic analysis was one of the most challenging issues during the design. From the standpoint of seismic resistance, the bridge deck is transversally supported by pylon and lateral frames. However, in the longitudinal direction the pylon represents the only support point.

The bridge length and variable soil conditions along the bridge axis required (according to European EC-8 design codes) analysis with different displacement time histories at foundation points. However, the absence of necessary geotechnical parameters made this type analysis not fully reliable. In order to overcome this problem, additional seismic approaches using site dependent response spectra and time history analysis due to characteristic accelerograms were used. Besides, the flexibilities of transverse frames are tuned in order to obtain acceptable lateral distribution of seismic forces. The whole project demonstrated the importance of cooperation between the designer, the seismological expert, and the design review engineer in seismic analysis and design.

Rudolf Aroch, Technical University of Bratislava, Slovakia

Nothing Lasts Forever Including Bridges, but We Can Do Our Best. Bridges are usually designed to withstand 100 years of working life. For this purpose, we design them not only for safety and reliability but also for durability to minimise excessive deformation, deterioration, fatigue, and accidental actions. Many bridges last much longer but many do not. For example, RC bridges suffer from corrosion of pre-stressing tendons, steel bridges from fatigue cracks in orthotropic decks. Not only a proper design but also good bridge construction, regular maintenance, detailed inspection, early repair, strengthening or rehabilitation, all play an important role in making bridges last.

Prolonging the working life of old steel railway bridges and increasing their load-carrying capacity by using reserves in the design was our goal. We used measurements under real traffic conditions to enhance the FEM calculation model by considering various positive influences (stiffness of connections, continuity of members, transfer of train loads into the bridge deck members, etc.). The use of lower partial safety factors based on the expected residual lifetime and a reduced, measurement-supported dynamic factor are also ways how to prolong the working life of our ageing bridges.

Stanko Brčić, University of Belgrade, Serbia

Numerical (preliminary) analysis of cable-stayed bridges. The main components of cable-stayed bridges are the deck and one or more pylons and cables that are inter-connecting the deck and pylon(s). Cables are acting as effective elastic vertical supports for the deck and are highly tensioned all the time. Due to cable inclination, as opposed to suspension bridges, both the deck and the pylon(s) are highly compressed, in addition to bending and torsion. Preliminary numerical analysis should consider several variant solutions and for each variant solution analysis should provide as much reliable structural info as possible in order to make a proper choice. Consequently, FEM analysis of the bridge, particularly in the preliminary stage, should be correspondingly advanced.

Bridge deck and also pylon should be treated as thin-walled beams (made of reinforced/prestressed concrete or steel). Consequently, FEM code should have thin-walled beam finite elements (with at least 7 DOFs per nodal point), based on the Second order theory. As opposed to standard FEM structural codes, which use linear and geometric stiffness matrices in their second order formulation, the proper second order formulation should be based upon the “exact” stiffness matrix (elements of the matrix are trigonometric and/or hyperbolic functions of the normal force). Also, cable elements in the standard FEM structural codes are usually truss elements with Ernst modulus of elasticity to simulate cable sag. However, cable finite element formulation should be based upon the corresponding catenary theory in order to simulate stay cables and prestressing tendons more reliably.

Viktor Markelj, University of Maribor, Slovenia

Experiences from Slovenia. For a great bridge design, it is not enough just to ensure safety and serviceability according to technical codes. For excellence, the bridge must have something more, a primary idea that gives identity and additional value to it. This may not necessarily be a record span or a visual significance, it could also be a sensitive response to environment, a structural innovation, use of new materials or special detailing.

In the past, engineers needed wide theoretical backgrounds, talent, and experience, while today, they can save time and reduce risk using advanced IT solutions, which, however, cannot replace understanding of structural logic. The strongest trend today is increasing durability and extending life span of the structure, which gives the long-term sustainability and respect that only old bridges get over the history.

Zoran Kovrlija, Belgrade, Serbia

Bridges for all times. It has come a long way in the World history of bridge construction; and if the Period of time we reduce to the last 500 years, and cross the path from beautiful stone arch bridges of Middle Ages, to impressive and grand suspension and cable stayed bridges that have been built all around the World in the last 30 years - that gives me a strong impression on the aspiration of bridge constructors to make the longest possible spans, longest possible bridges, highest possible piers …. Competition in records and grandiosity. Although spectacular in dimensions, I believe they will remain in the shadow of Ponte Rialto, Pont Carrousel, Brooklyn bridge, etc. For sure they will. And for the understandable reason.

Dealing with the design of bridges at the time of transition from stru analysis by Kross or Kani processes, to computer programs equipped with all kinds of wizards, the path that has been passed brought good sides to the bridge design, but also opened many wrong paths. The good sides we know - the constructor is freed from wasting time in a painstaking process of solving equations of equilibrium and dealing with mathematical operations. And the wrong sides are obvious – an average engineer and “AutoCAD” user believe to be a bridge constructor - from the fact that typing input data required by the software, importing bridge model from the “AutoCAD” drawing, picking up Loads from the load library, selecting all options that the full program offers, including dimensioning, drawing reinforcement ….. then pressing ENTER and printing 1,000 pages of program output. Called “Technical Documentation for the Bridge”.

2.2 Construction

Aarne Jutila, Helsinki University of Technology, Finland

Experiences from Finland. A good bridge should fulfil the following requirement in balance: functionality, economics, technics, and aesthetics. **Functionality** means that the bridge comes up to demands and expectations of the society for which it is planned and constructed. **Economics** means that investment made for the bridge is reasonable, not necessarily the lowest, considering its whole lifetime. **Technics** is the most important requirement and that is why the main designer should always be an engineer. In this respect the load-carrying capacity is of key importance. The users, ordinary people, cannot be expected to understand that even a bridge can collapse. Finally, **aesthetics** is the issue that everybody is able to argue about. As the world-famous bridge builder David Steinmann stated: “No bridge builder is worthy of carrying this name before he is filled with the passion to build his structures beautifully.” [18]

ICT – Information and Communications Technology – has rapidly changed all fields of engineering, including bridge engineering. Structures of today would not be possible without ICT, and development towards more and more imaginative structures and bridges will continue. Even more sophisticated computer programs than those we have today will be developed, not only for design, but also for construction purposes. Automatization will cover all phases of bridge engineering enabling cheaper and quicker realisation of even most complicated structures. Demands for education will increase, because need for better educated engineers, who are able to see the world with open eyes, will steadily grow as well. That means huge opportunity to young people, who are ready to meet the new challenges with enthusiasm and open-minded ideas. [19]

Bratislav Stipanić, University of Belgrade, Serbia

Bridge constructions through centuries. Ancient bridges were built as arch structures from wood or stone only. The use of steel as a replacement for wrought iron (first used for Coalbrookdale Bridge in 1779) extended in last quarter of 19th century: steel arch bridge on Missisipi River (159m span), Brooklyn Bridge – suspension bridge (486m span) with cables of hard steel-draw wires, and Forth Rail Bridge (521m span) with steel truss cantilever construction. First half of 20th century was noted by steel trusses for beam, arch and suspension bridges; while arch and beam structures dominated as reinforced concrete bridges. The development of design modelling, welding technology, and high strength steel wires had a crucial influence on bridge constructions from middle 20th century. The prestressed concrete, composite, and steel bridges (with orthotropic deck) became dominant. Future directions: further improvement of bridge reliability (safety, serviceability & durability) by development of design modelling & monitoring with ICT application and building materials & construction technologies.

As a structural engineer involved in design (author of designs & scientific papers) and construction (supervision engineer) in several large bridge projects, I wish to underline the development of cable-stayed bridges for long span bridges and bridges with limited structural depths. Advantages in construction erection and aerodynamic behaviour (in comparison with suspension bridges) result nowadays in significant application of cable-stayed bridges for longer spans (200-1100m). This is enabled by new technologies of production & erection of stay cables and sophisticated design calculations & modelling. Additionally, the bridge layout architecture is enriched by wide combination range of pylon types, stay configurations, and girder appearances. Nowadays, modern attractive architecture layouts are required for urban bridges and distinguished landscapes.

Dragan Bojović, Belgrade, Serbia

Another view. Since ancient times, people have strived to bridge waterways and connect their banks. Initially, log bridges were made using tree trunks, later stone was used for the bridge structure, and in the modern times the most commonly used materials are concrete, steel, and prestressed concrete. Initially, the spans of the bridges were small and structural systems simple, so wood, stone and other materials found in nature could be used to build bridges. Later, with the advent of modern materials, the spans of bridges increased significantly, and structural systems became much more complex. The choice of materials for bridge construction has been greatly reduced, so almost all modern bridge structures are made of concrete and/or steel.

Steel, concrete, and post-tensioned concrete with high-strength steel are the materials that have enabled various structural systems and bridging of large spans. The challenges faced by constructors in view of the growing spans of bridges and the longer durability of structures, require materials that will enable them to reach the set goals. Ultra-High-Performance Concrete (UHPC) is an 8 to 10-fold improvement of the traditional concrete in all respects, and this gives designers greater freedom in the designing the bridges. Ultra-high compressive strength in structural sense can significantly enhance composite steel and concrete structure. Based on the personal experience of the author as an expert in the application of modern materials in the design and construction of bridges, a much larger number of composite structures with steel and UHPC should be expected in the future.

Gradimir Srećković, Belgrade, Serbia

Cable Stayed Bridge. In Serbia, during the last three decades, a number of cable-stayed bridge were built. The double-track railway bridge, across the Sava river in Belgrade, is one of the first bridges of this type ever built in the world. The pedestrian bridge over the river Sava, between Sremska Mitrovica and Mačvanska Mitrovica, is specific in the fact that its aspect ratio (the ratio of the range and the width of the bridge) is equal to 35, which, at the time, was unique in the world.

The road bridge over the river Danube in Novi Sad, is among the first bridges in the world in which the free surface of the main span was applied. At the time of its construction, this bridge had the main range that represented the world record. In addition, this bridge is a unique example of a bridge in the world, which was destroyed during the NATO bombing and then rebuilt, based on the original project.

Zeljko Ašanin, Belgrade, Serbia

Underwater surveillance for Bridge Engineering. In each and every engineering and non-engineering project, the most important issue is that foundations for design and implementation are solid and able to withstand all the requirements of the mission, as well as to be able to withstand all the future requirements of a possible future vision that the generations to follow may create. In the case of bridge engineering, this means that the soil underneath (both inside and outside the river banks) has to be analysed in all relevant aspects and presented to designers with absolute perfection, as far as all the relevant details. This needs a special education at the university level. Parts of this special education should be dedicated to history and archeology, which would build important elements of social responsibility into the related engineering activities.

Actually, in the educational activities of his ancient academy, Plato was stressing not only geometry, but social responsibility, as well. If we refer to more modern times, then one could state the following: Of the four sculpture faces engraved into the Rushmore Mountain (of the four past US presidents), three belong to surveyors by formal education, with a strongest sense for social responsibilities. During the decades of my professional engagement in all relevant aspects of remote sensing for river bed analysis, I became aware not only of many professional rules and tricks of the trade, but also of the fact that bridges connect not only people, but times as well (kinds of underwater time machines). It is amazing how many different artifacts of historical value were found inside river beds (able to shed light on the history of a future bridge position). It is even more amazing that some of them were of artistic value (even the artifacts of artistic value were discovered during many years of exploration). I was fortunate that most of my mission activities were specifically in Belgrade and generally in Serbia, but also at most of the continents of this Planet, so I could compare and I can state that Belgrade (ruined to ground dozens of times in its history) and Serbia (with an even higher rate of being ruined down to ground) are definitely among the epicenters of the globe.

Zoran Gapić, Skopje, Macedonia

Experiences from Macedonia. Analyzing the latest collapses of big bridges, which mostly occur as extremely quick breakings, it seems that they are mainly due to the bad maintenance and insufficient monitoring of the parameters of the bridges. Therefore, I suggest in the design phase to include the following:

(A) The methodology for the monitoring of the bridge, with the special attention to the strength, bending, the state of the bearings and expansion joints, as well as other parameters of the construction and the esthetic. Independently of the BMS, the design should include positions and elements for monitoring of the structure recommended by the designer. In that case there is a continuity in the chain of responsibilities. (B) The systematic control of the behavior of the bridges during exploitation is a pre-condition for the safety and the durability of the bridges. Discussing the issue only afterwards, produces big human and material damages when the phases design, execution, and maintenance are totally separated and not connected systematically. The project must include elements that affect the regular inspection, maintenance, and conclusion whether the bridge is within the parameters that are designed and revised. What is especially needed is the bridges in the city, which, as a rule, are special structural constructions.

2.3 Aesthetics

Nevena Daković, University of Arts, Belgrade, Serbia and Academia Europaea, London, UK

Bridges as art objects. Ivo Andric, Yugoslav Nobel Prize winner, in his short story, Most na Zepi/The Bridge on the Zepa (1925) writes about a deeply symbolic bridge: „It seemed as if the two banks had each spurted a foaming jet of water toward one another, and these had collided, formed an arch, and remained thus for a moment, hovering above the Chasm“. Bridges, being among the noblest and the most elegant of human edifices, span over multiple metaphorical and symbolic chasms in time, space, identity, memory ... and are the recurring trope in art and media texts, fiction, visual narratives…

The film Something in Between (Nešto između, Srđan Karanović, 1983) – a melodrama spanning across continents – is construed around emotionally and symbolically charged images of bridges connecting people, cultures, and civilisations. The story begins by the Brooklyn Bridge, continues in Belgrade seen from the Gazela and Branko's Bridge and ends on the Galatta Bridge in Istanbul. Bane Bumbar (Branko Cvejić) at the end of every episode of the cult, nostalgic TV series The Unpicked Strawberries (Grlom u jagode, Srđan Karanović, 1975) walks over the Old Railway bridge to New Belgrade, to the symbolic space of the future, himself resolved to grow up and „become a man". Similarly, shots of bridges in New York and Belgrade, as seen in the film Here and There (Tamo i ovde, Darko Lungulov, 2009), instill the feeling of Belgrade as the „New York of the Balkans". Bridges of Novi Sad, savagely shelled during the 1999 NATO bombing, are affectively commemorated in two short films. Monument (Spomenik, Mika Antić, 1967) remembers Ujvidek Raid in 1942 when Hungarian Nazis killed thousands of Serbs and Jews on the bank of frozen Danube, close to the bridge. The cold black iron and steel construction of the bridge standing ominously against the whiteness of the snow embracing the thick, half frozen river and delicate flower wreaths thrown into the Danube in memory of the perished, beloved ones. The Name of the Game (Dragan Zivancevic, 1999) ironically shows carefree, happy barefoot sun-tanned boys playing football on a large concrete slab beside the river, accompanied by the music from Buena Vista Social Club. However, the camera slowly pulls back to reveal that the match is being played on the bridge destroyed in the NATO bombing. In the books of Ivo Andric, Orhan Pamuk or Vladislav Bajac bridge is an emblem of fractured, traumatised and hybrid identities of cities and people on the crossroads, such as the Balkans. For Mehmed pasa Sokolovic or the Grand Vizier the bridges are more than just a personal legacy. They symbolise the return of the repressed – their Bosnian, orthodox origin, sweet memories of mothers and families, of everything they lost when they were forcefully taken to Constantinople There is no "bridge too far", only the bridge over „troubled water", the one each of us has to cross literally and metaphorically while following the fine, invisible paths of one's life.

Peter Gabrijelčić, Ljubljana, Slovenija

The architecture of bridges. Bridges have always been an important element of architecture. They are a thrilling point of transition or Crossing from the known to the unknown. It connects two previously unconnected spaces. When a bridge is conquering the distance, it does so in both a visible and measurable manner. A bridge is a generator of social contacts, it's a space that is always exceptional, as a river crossing or a crossing over vertiginous abysses or canyons. It is a special place where people are more exposed to the danger of depths and therefore more susceptible to mutual contacts and interviewing in their vulnerability. As architects, we can use our skills to even accentuate this feeling and encourage people towards mutual communication. In the majority of my projects, this was my fundamental tendency, and I hope that I succeeded in fulfilling the expectation as that my bridges would truly become places of connecting people. In designing footbridges, the architect is given a freer hand. A footbridge, only intended for pedestrians and cyclists, differs from a classical bridge with motor traffic; it can be leaner, and the construction can be thinner and more poetic. Such bridges can be an important generator of social contact and public outdoor living.

Bridges are mostly in the domain of civil engineers, as most work in bridge planning falls to the structural engineer. An architect is, if nothing else, a useful interlocutor, because, with a broader and multi-layered view of the phenomenon of space and with a critical distance towards the construction, an architect can see a bridge in different terms, not only in functional, construction, or price terms, but also in terms of urban planning, the environment, landscape, design, sociology, psychology, and alike. Both parties should have at least some elementary knowledge of the other discipline. In this way, they can be equal interlocutors at a general, human level, where they share a cultural motivation: to create something great, a superior work. Collaboration between architects and constructors is especially important when we design monumental bridges. Bridges of that size play a role of a city landmark or of a landscape icon in space. They are important geographical orientation and reference points, an urban development accelerator and, at the same time, they also enable pedestrians to have an intimate experience of the river area. By using ICT, we can find unique and iconic construction and architectural solutions and adapt it to the needs and perceptions of diverse users.

2.4 Vision

Alexander Jiponov, Sofia, Bulgaria

The extradosed prestress bridges. The extradosed prestress bridge concept is relatively new in the field of Structural and Bridge Engineering. The first time when that system was applied was in 1994 in Japan. Since then, it becomes a unique type of structure for its advantages over other bridges. Extradosed bridges could be described as a concept between prestressed bridges and cable-stayed bridges. A stiff deck extradosed bridge shall have a similar behaviour to the prestressed bridge's, thus avoiding high stress oscillations of stay cables and, consequently, avoiding fatigue conditions associated with anchorages and tendons present in a slender deck extradosed bridge, which behaviour is quite close to the cable-stayed bridge.

In the design of extrados bridges two main approaches are developed. The first one aims a low tension in the cable-stays and the appropriate stiffness arrangement in bridge superstructure and substructure. The second one considers rigid pylons and slender deck which is more similar like the classic cable – stay bridges. The extradosed system is a competitive solution for spans with length between 100-200m. They are preferable for seismic regions comparing the cable-stay bridges. In cases where there is also the railway traffic on the bridge, they are a relevant solution.

Goran Tadić, Belgrade. Serbia

Guiding thoughts, based on my past experiences in bridge design. The quality solution is when numerous railway and road bridges can be designed and built in a row and in a short term but still have a long service life. Leading designer should present the design solutions to co-workers when it becomes acceptable to him. Listening, weighing, and accepting suggestions from associates and experts of different professions bring the solution to the optimum. All teams and individuals in the project should timely exchange necessary information. Learning from your own and others' mistakes is valuable. The design is successful when the number of calls from the construction site is minimal or missing.

Experiences helped me create my general views and guiding thoughts. Great knowledge and results are not achieved during working hours only. University-acquired knowledge is a foundation that should be upgraded throughout the whole working life. Designers have previously acquired new knowledge from the paper – professional and design books, but today, they are adapting to rapid changes. Upgraded software, information and communication technologies have created a work environment in which designers can realize the most complex structures and communicate with others across the world in real-time. Building information modeling is not only a process for standardizing and tracking the designs, construction methods, materials, maintenance, and costs over bridge life-cycle, but it also becomes a powerful tool to support the designers' imagination, ideas, and creativity.

Julio Ramirez, Purdue University, USA

Smart Resilient Communities - road infrastructure empowered by data science, advanced computing and materials. Grand challenges facing our roads and bridges are: (A) Upgrade Aging Infrastructure and (B) Achieve Smart and Resilient Infrastructure. Addressing research questions that answer these grand challenges would provide bridges and roads able to support communities to stand, adapt and recover from natural hazards and successfully perform during service life.

The future of our bridge and road infrastructure is empowered by the disruptive technologies such as data science, advanced manufacturing, meta-materials, bio-inspired engineering solutions, and advanced computing. Envision the following breakthroughs: (A) A bridge/road able to ingest the weather report and driving conditions, and alert a fleet of autonomous vehicles; (B) A bridge able to detect overweight vehicles, reporting drivers; (C) A bridge able to self-diagnostic condition after an earthquake, and report accessibility; and (D) Entire bridge replacement in a few days.

Mladen Uličević, University of Montenegro, Montenegro

Experiences from Montenegro. The role of the bridges and the purpose of their construction, from the past to date, has remained the same: to defy the natural obstacles, overjump them and so enable and improve the quality and speed of communication among people. As this human need grew, so, in parallel, did new technologies for bridge construction, often having a decisive influence on the bridge solution. Certainly, ICTs have their place in this, enabling designers to "feed" bridge facilities production from any distance/place in real-time.

However, equally for both historic stone Roman aqueducts and contemporary cable stay bridge megastructures, it is valid that the final solution quality predominantly depends on the level of compliance with the basic principles of design of bridges: the peak lies in the simplicity and purity, and aesthetics must be the reflection of strength and stability of structure and of rational forces flow in the bridge. The more I do this job, the more I realize that the idea of creating a bridge is the pearl of wisdom in itself. I guess that's why every new task, whether it's a simple little obstacle or a wide river/bay, evokes in us a strong driving energy and passion to do our best. And never forget: the sophisticated structural analysis software, as well as the ICT, are just powerful tools that help the engineer to optimize his design concept. None of this can be a substitute for inventiveness, experience-based skills, and the knowledge of an engineer who must permanently remain a central decision maker! Let's conclude: be conservative using basic principles, be brave using contemporary technologies!

Vukan Njagulj, Belgrade, Serbia

Standards in bridge constructions. Standards are the summary of provable facts, but also a cumulative reflection of personal opinions and experiences, both positive and negative ones. Because of this, they were different from country to country, which contributed to critical thinking. The EC has imposed itself as absolute truth, so now only what is written in the EC seems to be allowed. Everything else is forbidden, which almost disables the engineering approach to problem solving. The computer is an extraordinary invention, but still only a tool. However, the computer has also imposed itself as an absolute connoisseur, often resulting in a lack of control and understanding of the results obtained. In addition, the use of computers, not knowledge, very often leads to a significant increase in material consumption and the creation of purposeless calculations.

The Internet is also an extraordinary invention, but it should be borne in mind that the information available is often very diffuse and unreliable. The same is true, to a much lesser extent for sure, for technical literature as well. When collecting information about a problem, access must always be critical. Easily accepting the information, solutions or data provided can be very misleading. The bridge layout should be designed taking into account at the same time the characteristic structural details, the static specificities of the structure, and especially the perceived and potential problems in execution. The static functioning of the structure must first be considered logically and then more detailed calculations should be made.

3. JUNIOR EXPERIENCES

3. 1. Design

Goran Milutinović, Indianapolis, USA

Experiences from Indiana. A "good detail" can be defined as the one which deteriorates slowly (so doesn't require expenses for future repairs) and which will not fail under dynamic (e.g., bridge unseating during earthquakes) or fatigue loading. An important feature for improving the bridge design and implementation is a continuous learning which detail is "a good detail" (for example, a such fatigue classification of steel details is done in [9]). This will enable to avoid "bad details" in the new designs and to detect them on the existing structures during inspection or load rating. It does not mean, however, that it is necessary to focus on increasing the design service life to more than 75 or 100 years, because the traffic demand undoubtedly increase over time. At the end of 75-or-100-year service life (or sooner), bridge will probably have to be upgraded or replaced due to larger traffic load and volume, although it hasn't worn out [10].

Finally, careful usage of computer software (with sound engineering judgement) and thorough quality control procedures are of crucial importance for the future of bridge design and implementation. Negligence of these two aspects (e.g., due to requested work speed) are most probable causes of future design errors.

Igor Vučković, Belgrade, Serbia

Suspension bridges. During my career as a junior bridge civil engineer mentored by several experienced engineers in the field, I learnt that: One of the many issues which follows the construction of every bridge is how to achieve the final configuration of the bridge throughout construction. Single span suspension bridges are not an exemption from the rule, just the opposite, due to the effect of high geometrical nonlinearity of the system, which is manifest itself during construction stages as a result of large displacements of the main cable. Nevertheless, the final configuration should satisfy the following criteria for dead loading: evenly distributed bending moments in the bridge deck; zero bending moment in the towers and vertical alignment; even forces in all hangers and also vertical alignment; main cables should obtain designed dead load cable sag. Initial unknowns which are necessary to obtain the final configuration are the following: unstressed cable length; initial cable sag; tower setback due to prestressing force; and unstressed hanger length. [11-17]

In order to achieve the target, structural system should be accurately set in the initial construction stage. Prior to construction, hanger nodes and tower nodes should be marked on the unstressed cable. Main cables should be mounted onto previously erected towers, thus the marked nodes on the cable match the splay saddle on the tower. Hangers should be mounted with appropriate unstressed hanger length and attached so the hanger clamps match the marked positions on the cable. Appropriate prestressing force in the backstays on the side spans should be applied. As a result, towers should obtain the correct initial setback and the main cable should obtain initial sag on the main span. During the following stages, performed symmetrically from the middle of the suspension span toward the ends, erection segments should be mounted and attached to the hangers. Consequently, in the final stage, suspension bridge should satisfy the criteria and obtain the correct reference configuration.

3.2 Construction

Božidar S. Furundžić, Belgrade, Serbia

Small Bridge Building: Compact Site Lesson. Bridge building is a complex technical venture. Civil engineer professional work in contracting has a limited time frame. Young structural engineer wants to enrich academic knowledge with practical experience and the best school for bridge building lessons is a site. Location determines bridge context (type, span, material). The span is a key characteristic and chiefly defines building period. Every bridge building scenario is similar in constructing steps, but the site lesson duration is different. According to own experience acquired, a small bridge building represents the compact site lesson. Some key factors of a successful bridge construction are underlined below.

Clever design solution is essential base of a successful construction. Even the best contractor cannot fix bugs in the design solution. Crucial are key technical staff, planning, construction stages organization, qualified workers, and professional supervision. Detailed technical preparation, triple numerical control, and expert approval are indispensable. Mechanization, equipment, materials quality, and attested bearings are needed. Trial load is one of the most important stages because it simulates exploitation load and, after positive results, the bridge can be put into traffic. Everyone in the construction chain, from exploration works and foundation excavations to technical inspection and trial loading, is responsible for a successfully built bridge.

3.3 Aestetics

Danilo S. Furundžić, University of Belgrade, Serbia

Bridge as the most significant visual dominance. Infrastructural systems incorporate dots and grids that enable system integrity. Networks of roads are transport grids, where accompanying buildings of the transport infrastructure (crossroads, overpasses, stations, garages etc.) are transport dots. From an architectural point of view, the transport infrastructure system, that supplies a city with efficient mobility, represents a visual urban environment. The transport infrastructure dots and grids create human visual experience of the city. Perception of these elements forms series of recalled information that characterize the relevant location. Visual dominance appears as a land marking milestone of the built environment. The dominances are elements around which our mind sorts and stores information about space.

The bridge is a visual dominance that divides the urban space into bridge surrounding space and space further away. This bridge visual domination is emphasized psychologically. As the city panorama can be viewed best from the edge of obstacle that bridge spans, our impression of the city is often connected to such visual experience. Pictures of the city panoramas, river banks and bridges are intertwined. Visual experience allows the mind to remember the environment easily and the bridge becomes important architectural element of the city. The bridge is the most significant visual dominance in the cognitive map of a city. And the city is best remembered by its bridges.

3.4 Vision

Dušan Isailović, University of Belgrade, Serbia

A computer-assisted management view. Safe and fast mobility of people and goods is one of the greatest achievements of civilization. What mostly contributes to the safety and speed of so much appreciated mobility is the good quality of the traffic infrastructure. Once constructed, the infrastructure must be timely and properly maintained. Being critical links in the infrastructure network, bridges require special care. For the past thirty years, highly sophisticated systems named Bridge Management Systems are used to track conditions of tens of thousands of various bridges and prioritize maintenance actions. However, accidents such as the collapse of the Morandi bridge in 2018 indicate a need for significant improvements in this field.

Technologies such as Computer Vision, Remote Sensing, Internet of Things, and Artificial Intelligence can be combined with the Building Information Modeling and Structural Health Monitoring to improve the Bridge Management by collecting significantly more data about bridges, understanding this data, and visualizing it. 3D point cloud of a bridge provides a much more reliable base for the condition assessment than an inspector's eyesight. Damages on a bridge surface can be automatically detected on the point cloud using machine learning techniques and later introduced to the Bridge Information Model along with the data from the embedded extensometers.

Nikola Tošić, University of Belgrade, Serbia

The value of mentoring. Junior engineers need and want mentors and role models. Junior engineers want to be part of a tradition and community. Career and personal growth are the greatest in a supportive environment where it is safe to try new things. Junior engineers want to learn, travel, connect with colleagues from around the world – they should be allowed to do so. If you are a senior engineer, remember that being a mentor is a two-way street, and if you are a junior engineer, remember the same! We must not forget that junior engineers of today are the senior engineers of tomorrow.

The junior engineers of today are growing up and learning in a rapidly changing world. In order to find their place in it, they need but also want the help, support, and mentorship of their senior colleagues. Structural engineering is an extremely responsible job and no junior engineer can go through their career alone. Therefore, junior engineers should be better integrated into the engineering community and society through various associations and organizations. Although they may be inexperienced, they are the most enthusiastic members of any organization – they should be provided opportunities to safely explore their ideas. Only when senior engineers realize that they can also learn from junior engineers, and only when junior engineers take up this obligation, our community will advance.

4. CONCLUSION

The goal of this article is to bring together and to synergize the experts from four different regions (exYu, EU, US, and Israel) active in four different aspects of bridge creativity (design, construction, aesthetics, and social impact).

This goal is a part of a wider mission of IPSI Transactions journals, to create a database of expert opinion articles on various research and development fields, and to create conditions for a symbiosis among contributing authors.

The mission of IPSI Transactions is a product of the vision that was created about two decades ago, aimed at generating a vector of journals that focus onto renaissance-type of multi-, inter-, and trans-disciplinary research in science and engineering, tangential to ICT.

The vision that led to the above described structure and contents of IPSI Transactions was created by Hiro Fujii of Japan, Martin Perl of the USA, Veljko Milutinović of Serbia and Montenegro, and Erich Neuhold of Germany, The last one was responsible both for the vision behind the publishing effort and for the providing of the seed money from the German Fraunhofer IPSI Institute in Darmstadt that enabled the entire vision to get materialized.

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