# Digital Libraries as Technological Environments. Collaboration of Work and Future Perspectives

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#### Abstract

The nature of libraries has changed rapidly with the advent of technology, so far as to change the very way of understanding the library itself. In this paper we examine the impact that digital technologies have had on library workers, and note that so far technology has only been used to transpose the standard library practices, and that little has been done to fully exploit the new opportunities it introduced. To overcome this situation, we propose a graph-based organization of DL data, based on a technology mixing DBs and ontologies. We also propose a holistic data schema allowing to store information that is usually neglected by traditional cataloging and description standards used in libraries. This would enable the use of AI techniques that may significantly expand the effectiveness of data processing and may dramatically improve the exploitation possibilities of documents.

#### Keywords

History of Technology, Digital Libraries, Information Retrieval, Knowledge Graphs

#### 1. Introduction & Motivations

The history of the profession of librarian is inextricably intertwined with the history of the library, especially that of the last decades. In the United States, and then in Europe, the nature of libraries has changed rapidly since the middle of the last century, when technology has forcefully become part of these realities. These structural changes have initiated a sort of revolution that has changed the way of understanding the library itself. In this study we intend to examine the impact that new digital technologies have had on library workers, and to propose a new approach that overcomes the limitations of the current practice.

A library catalogue card contains information about the object being catalogued and the location of the object within the library. The traditional record-based approach has successfully served the needs of library users, researchers and practitioners for many decades. The enormous growth in production, types and availability of documents, the opening of their use to a wider public (with different background, goals and perspectives), the advent of digital technologies, and the convergence of many different traditionally separate disciplines call for new and advanced organization strategies, and new ways of exploitation, for the documents and the information they carry. This requires a change of paradigm. It is necessary to deconstruct the traditional record-based approach with predefined fields (author, title, etc.), and to move to a reticular description, in which all the entities involved in a description 'live' with their own dignity and can be related to each other, rather than being just field values in the record. Such a new setting is also instrumental to broaden the focus of the descriptions, from a fixed set of formal parameters of the documents in the library to a larger and more variable set

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including also information concerning their physical support, content, context, and even use. We have called it a holistic description approach.

In the rest of this paper, we first overview the evolution of libraries in the last two centuries, and then we describe our proposal for a new approach that expands the boundaries of library descriptions and enable advanced exploitation based on AI solutions. Then, we conclude the paper.

### 2. Paths from the past to the future

At the end of the 19th century, Melvil Dewey launched a process of professionalization of the librarian's activity, helping to found, in 1876, the *American Library Association* (ALA) and setting up the *School of Library Economics at Columbia College* in 1887, the first specialized school in the world. He also proposed a "centralization" of cataloguing efforts. As a reformer, Dewey also initiated those educational processes that he considered fundamental to designing the emerging profession of the librarian, suggesting, among other things, that the ideal candidates were the women who, by their nature, paid more attention to detail and had a strong "moral sense". Dewey also argued that they had the benefit of being paid only half as much as their male counterparts and could be counted on for their dedication to their work. These were probably his motivations for strongly opposing the board of trustees of Columbia College in 1887, who did not welcome women in the *School of Library Science*, by starting classes in off-campus premises with twenty students, seventeen of them women. [1:85-93]

At the turn of the 20th century, US government agencies had started a process of promoting public libraries, especially in rural areas of the country. By attracting the same workforce as the school system, which was predominantly female, women had the opportunity to choose an activity related to libraries: female students were instilled with a fervent desire to become 'book missionaries' with the aim of spreading the culture of reading.<sup>2</sup> [2:2].

However, this philosophy began to lose strength when, in the 1920s and 1930s, the utilitarian aspect of book distribution took hold, geared mainly towards the consumer who had to be guided in his choices by library managers. The utilitarian philosophy sought to improve the division of labor and raise the status of librarians by attracting more men and separating the managerial functions from lower-level services. This division was further exacerbated during the period in which the information technology changed the face of libraries: the program of "automation", which had been initiated in the 1960s, taking advantage of the widespread techniques of punch cards and microphotography<sup>3</sup>, had begun to delineate what would be the "library of the future", while leaving unchanged the "gender dynamics of the present".

#### 2.1. From cards to ASCII characters: sharing between librarian and user

From April 21 to October 21 1962, the American Library Association (ALA), for the first time, secured a spot at the World's Fair in Seattle. The exhibition was designed primarily to imagine the role of technology in libraries, so much so that, in the assigned area, an imaginary line clearly divided the library of the "past" from that of the "future": on the one hand, there was room for traditional books placed in the classic shelves managed by librarians, on the other hand, there was a Sperry-Rand Univac Computer with which, through some insiders, the logic of the systems of digitization of catalogs was shown [5].

Sometime later, historian Jesse Shera, dean of the School of Library Science at Case Western Reserve University, developed a kind of "code for library computerization" that he illustrated at the 1964 World's Fair in New York<sup>4</sup>. Its purpose was to send a signal, not only to the trade show audience, but especially to the multitude of professionals who attended, of impending change. The rise of

 $<sup>^{2}</sup>$  From 1880 to 1920, women went from a minority (20%) of the profession to a majority (75%) of the profession. In 1920 the number of professional women practicing librarianship increased 236 percent, most of whom were recruited from the middle class [3].

<sup>&</sup>lt;sup>3</sup> The microcard was a three-inch-by-five-inch card designed to contain, on the one hand, the cataloging of an article and, on the other, the miniaturization of its full text. [4]

<sup>&</sup>lt;sup>4</sup> Jesse Shera (1903-1982) was one of the most important figures in librarianship laying its foundations in the 1960s. For Shera, it was crucial that there be collaboration between librarians and researchers in other disciplines and so he was a strong advocate for the introduction of information technology at a time when this trend was strongly opposed.

computer science threatened to divide librarianship and overwhelm what was its humanistic core: «being traditionally humanistic, librarians doubt their capacity even to utilize anything that is scientifically derived.» [6:742] The classical ideals that saw the "library" as a place to cherish freedom of speech, as a safe haven of information and a repository of memory, that is, places dedicated to serving the needs of the community, pushed to designate only women to be guardians of morality and to be promoters of reading, inevitably shifting the male contribution to projects in which library science and economics were not only predominant, but also crucial to continued change.

As dean of the School of Library Science at Western Reserve University, Shera strongly supported the establishment of the *Center for Documentation and Communication Research* to promote information systems as a means of enabling librarians to operate at a higher level of information storage and retrieval. Over time, however, the Center proved to be a failure; it was entrepreneurial rather than academic in nature, meaning that its main purposes were related to the promotion of specific software rather than the dissemination of problem-solving methodologies. According to Margaret Kaltenbach, Shera's collaborator, the *Center* was identified more as a school of computer science than anything else, and this represented its main limitation. [7:157] From this point on, Shera no longer indicated what was the best path to follow, distancing himself from both technology and the fear of its dominance and never taking a clear position: «The library is not a machine shop in which knowledge is fabricated by mechanical devices [...] we regret the indifference, and even hostility, of many librarians to the advantages the new electronic devices, which are as yet only in their infancy, can give to improving the efficiency of man's access to recorded knowledge.» [8] Librarians could learn from "technologists" and leave the Stone Age behind.

Along with mathematicians, systems designers, hardware manufacturers, operations researchers, and computer programmers, they were therefore concerned with understanding «how interwoven are their interests and how overlapping their responsibilities» in libraries. [9:X] It was obvious that a positive result could only be achieved with cooperation between the various figures.

In the decades to come, the computer science began to be associated with everything that concerned the interaction between the worker and the machine. The enthusiasm due to the adoption of computers had stimulated the launching of numerous experiments, but more credibility and confidence was given to those resulting from the proposals of those in positions of power. Among these, we should undoubtedly mention the project presented by a small group of representatives of the academic libraries of Ohio, whose leaders were Ralph Parker, director of the *University of Missouri Library* and Fred Kilgour, librarian of the *Yale Medical Library*. Their proposal was to use large, cumbersome *mainframe* computers<sup>5</sup> to initiate what is known as cooperative, computerized, networked cataloging of library resources. To that end, in 1967, Parker and Kilgour had founded the *Ohio College Library Center* (OCLC), a committee that was initially joined by 54 Ohio college libraries and that only fifty years later would include more than 16,000 members in 120 different countries, serving libraries of all types with more than 40 million research requests each day. [10] The exponential increase in the number and quality of the documents that made up the electronic catalog led to the conception of new projects that gave life to the so-called OPAC (*Online Public Access Catalog*), catalogs aimed at publishing documents on the web that could be accessed directly by users.

The effects were recorded mainly as an advantage for female librarians whose tasks were automated, causing further negative repercussions on their work which was considered simplified and, consequently, devalued more. For cataloguers, already often considered less capable than library professionals, there was a strong fear that the new systems, such as OCLC or the more recent OPAC, could compromise their employment [11:87-97].

The marriage of library and information sciences seemed a far-fetched possibility to all those who gravitated around these spheres. The computers were assuming the role of protagonists, and, with the automation of office processes, it became almost mandatory to rethink roles in view of these changes. These changes were interpreted, in library environments, in a conflicting way, as if they represented a direct clash between intellect/information sciences and services/library economics: technology could

<sup>&</sup>lt;sup>5</sup> Powerful centralized processors that from the sixties onward were used by large companies for computing operations. They occupied entire rooms, and, most of the time, were divided into several metal cabinets: hence the derivation of the term (*frame* that stands for "armor", in the sense of metal frame). Until the advent of departmental minicomputers and then of personal computers in the 1980s and 1990s, mainframes were the symbol of centralized computing.

have blurred those well-defined boundaries that had assigned precise responsibilities, rooted for decades [12:142-143].

In the United States, after 1980, a library that used card drawers for its cataloging system was considered behind the times. The catalog, which had been transformed from typed papers into bright ASCII characters reproduced on computer monitors, was beginning to become the real protagonist because it drew, without misunderstanding, the state of technological sophistication of the public space in which the library's patrimony was stored. Starting in the seventies, in fact, the availability of new computer technologies had caused a strong acceleration towards the use of computers and various methods of photoreproduction. The multiplication of libraries, together with the proliferation of numerous forms and dynamics of compiling electronic catalogs, had also led to the urgent need to coordinate these activities: international study committees such as UNESCO, the International Federation of Documentation (FID) and the International Federation of Librarians' Associations (IFLA-FIAB), were urged to unify bibliographic rules and systems in order to produce general cataloguing standards that would apply internationally. As a consequence, librarianship went through a real evolutionary phase, becoming a discipline that aimed to study and modify the organization and functioning of the library, focusing on the effects of technological changes.

The complexity of managing library services in an electronic environment required non-traditional skills that implied the emergence of new job positions closely related to information technology, necessary to appropriately manage the most current technologies: the electronic services librarian, the database coordinator, and the microcomputer specialist.

Professional training activities had the same repercussions. In library science schools, courses such as database design and computer programming came in with great force, putting cataloging, children's services, and library history on the back burner. [13:676]

#### 2.2. From the electronic catalog to the sharing in net

By the late 1970s and early 1990s, due to the lowering of computing power costs, nearly all libraries in Europe and the United States had completed the so-called automation phase. Press releases announcing the "closure of the card catalog" were the order of the day, as if to signify that the library was ready to face an "electronic future".

From this point on, the phenomenon that occurred was a kind of "turnkey market" for integrated library systems, with the consequent shift from locally developed software to primarily commercially implemented systems that followed general and collective technical standards. Having overcome and forgotten the problems associated with the flow and management of local work and operations, all libraries were then linked to these systems, resulting in significantly stronger and more independent organizations. Boundaries between internal competencies began to blur as staff responsibilities began to overlap: tasks traditionally performed by librarians were de-emphasized and often outsourced to external staff hired to support the library.

The sharing of catalogs on the "network" was therefore the real added value of the 1980s; it also became the main topic of discussion in librarianship and gave rise to a series of debates centered on the "practice of cataloguing". The result was that cataloguing was redefined and shifted from a humanistic and conceptual activity, coordinated by experts in classical subjects, to a manual and routine activity requiring only a minimal training process for unskilled employees [14]. Why these mutations? The only reference object of the library, the book, with the passage of time had turned into a general entity of "information" that did not always coincide with the "book" object and that was also identified with articles extracted from magazines, images, music CDs, videos, multimedia and hypermedia of various kinds. We were moving away from content, giving space, as Ruth Hafter points out, mostly to issues of data organization: «rules and procedures change» over time in a myriad of ways because they may need to be adapted to modern terminology, the latest scientific thinking, or innovative research practices; at the same time, users may evolve in their needs and demands; and, of course, the very technology for entering, storing, and accessing catalog data may change, affecting labor costs and delivery times for the required material [15:11-12].

#### 2.3. Digital Libraries

One has to go as far as 1992 to have a rigorous definition of a Digital Library. During the National Science Foundation Workshop held in Palo Alto, several specialists in the field met to sketch out a possible report urging the United States to finance such projects. A digital library was defined as «distributed technology environment which dramatically reduces barriers to the creation, dissemination, manipulation, storage, integration and reuse of information by individuals and groups.» These technological environments were to provide services comprising a well-defined «network architecture, a set of information resources, including textual databases, numerical data, images, sound and video documents, etc., and a set of tools for locating, retrieving and using the retrieved information.» [16:66-67].

The most widely used definition today is the one provided by the Digital Libraries Federation (DLF) and states that «digital libraries are organizations that provide the resources, including specialist staff, to select, organize, provide intellectual access to, interpret, distribute, preserve the integrity of, and ensure the persistence over time of digital collections so that they can be readily and economically accessed by a defined community or set of communities.» The preservation of information in DLs has three levels: hardware level, software level and the level of document encoding systems. The ageing curve of information technology is very rapid and imposes a periodic update of any information system; it goes without saying that this update often renders inaccessible information resources generated by obsolete tools.

## 3. A change of paradigm

The digital setting, with all the flexibility and opportunities it brings, can be leveraged to enable new ways of exploitation, for the documents and the information they carry, that can provide advanced and personalized support to multiple kinds of users with different background, goals and perspectives, overcoming the limitations of the traditional approach, born for paper cards and based on a fixed set of formal parameters of the documents in the library. Following the ideas of IFLA's FRBR [22] and LRM [27], we propose a change of methodological paradigm that deconstructs the traditional record-based approach with predefined fields (author, title, etc.), and to move to a reticular description, in which all the entities involved in a description 'live' with their own dignity and can be related to each other, rather than being just field values in a closed record. The proposed change requires an upgrade from the traditional Data Base (DB) setting to the Knowledge Base (KB) one, studied by the Knowledge Representation (KR) branch of Artificial Intelligence (AI). In fact, knowledge is defined as a network of information items in which the compound has more value than just the sum of the single information items' values. In KR research, a central role is played by Ontologies as the formal definition of the data model, specifying what entities, relationships and attributes can be expressed, and what properties they must fulfil. Knowledge Graphs (KGs) have been developed as KBs organized in graph structures (a straightforward and effective representation of networked information).

Then, once the boundaries of the records have been broken, we go beyond what proposed in [22,27]: we propose to further expand the scope of the descriptions to a larger and more variable set, including also information coming from the physical support of the documents, from the document content, from its context, and even from its use. We have called it a *holistic* description approach [17], resulting in a model (an ontology) that considers and brings to cooperation many different aspects:

- Formal, including usual metadata used in library records;
- Physical, including materials, processing and even mechanics, if relevant;
- *Content*, including:
  - *Textual*, at several levels (words, phrases or excerpts) and in different languages, also including grammatical information;
  - *Layout*, concerning the visual appearance of documents;
  - *Logical*, dealing with the roles played by the document's components;
    - Conceptual, interested in the meaning conveyed by the documents;
- *Context*, adding information that is external to the documents, but that may be useful or relevant to properly understand it;
- *Lifecycle* including process and usage data, useful for personalization purposes.

Traditional cataloging in DLs and archives only considered the *Formal* section. Of course, this must be compliant to existing DL cataloging and description standards: to this aim, our ontology includes, and is aligned to, several standard ontologies and metadata schemas, such as the Dublin Core Metadata Initiative (DCMI)<sup>6</sup>, the IFLA Functional Requirements for Bibliographic Records (FRBR) report [22], the Open Archives Initiative Object Reuse and Exchange (OAI-ORE)<sup>7</sup>, and OpenAIRE [23]. More are being added and aligned in new versions of the ontology.

All the other sections are peculiar of our proposal, and fundamental to our vision. The *Physical* section enables a description of the physical library/archive items, not just of their content. The Content section allows to tag the documents as a whole, or specific sections thereof, with keywords and concepts, to extract citations and excerpts, and to describe the specific items (Persons, Places, Events, Artifacts, other Documents, etc.) mentioned therein. Concepts, in particular, are represented as instances within the KG, so that they can be linked to other instances of any class in the KB in order to describe them. Several standard taxonomies can be stored, aligned and merged, also adding user-defined and/or domain-specific items. The current KB includes WordNet [28], the Dewey Decimal Classification (DDC) system [21] and a few taxonomies specifically focused on Computer Science and Engineering. Especially relevant (and fundamental to 'open' the records) is the Context (in the form of additional Persons, Places, Events, Artifacts, other Documents, etc.), that allows to interconnect the documents and their content<sup>8</sup>. Finally, the Lifecycle section allows to track the documents along time, connecting them to their uses and users. This enables the description of the processes underlying the items' exploitation, and the personalization of such exploitation (by describing user profiles and connecting their features to those of the items). In designing this part of the ontology, the user's point of view and the behavior that librarians pursue in their research are taken into account, in order to improve the KB in a targeted way. In fact, previous works in this and other fields [24,25] show the advantages of usercentered approaches for constructing KGs of information systems.

Some of the main classes currently included in our ontology are: Person, Organization, Place, Event, Artifact, Device, Document, Collection, Citation, IntellectualWork, ProcessComponent, User, PointOfInterest, Category, Language, Text, TimeSpecification. Many relationships are provided to connect the documents and their content to instances of these classes, and the instances of these classes to each other, providing the added value that we envisage in our holistic approach. Every instance of a class or a relationship is actually a record, described by a suitable set of attributes.

In addition to the expanded data model, we also propose to change the technological approach to KG representation. The solutions proposed by standard research in KR for representing and storing knowledge have parted from the mainstream solutions for DBs. Research in KR resulted in an established representation standard for formal ontologies (the Ontology Web Language, or OWL<sup>9</sup>) and associated data storage technology, called triplestores. Triplestores are based on the RDF graph model, consisting of sets of triples <Subject, Predicate, Object> where the three components are atomic (Uniform Resource Identifiers – URIs – or literal values). However, these attempts have failed to meet wide acceptance in industrial applications. On the other hand, significant success among big industrial players has been obtained by a new graph-based NoSQL DB technology, of which Neo4j is the most outstanding representative. It adopts the Labeled Property Graphs (LPG) model, that allows to associate sets of attribute-value pairs and labels to nodes and arcs. Nodes represent entity instances, arcs represent binary relationships on them, the attribute-value pairs represent properties, and the labels usually represent the type of entity or relationship. The LPG model is more expressive than, but incompatible with, the RDF one. Neo4j is schema-less, for which reason we propose to superimpose an ontology that acts as a schema.

We believe that DL data representation and management must still rely on DB technology, in order to ensure optimization and efficiency in data storage and handling. So, we propose a cooperation between DB technologies and the KR setting, that may boost the effectiveness of DL data management so as to support the needs of different kinds of users, providing them new possibilities for data exploitation and opening new opportunities to carry out their activities [18]. In our proposal, Formal

<sup>&</sup>lt;sup>6</sup> URL: https://www.dublincore.org/.

<sup>&</sup>lt;sup>7</sup> URL: https://www.openarchives.org/ore/.

<sup>&</sup>lt;sup>8</sup> E.g., two persons (authors of documents, or mentioned in documents) might both have attended an event, and no information about the event and their attending it might be available in any of the documents.

<sup>&</sup>lt;sup>9</sup> URL: https://www.w3.org/OWL/.

Ontologies play the role of data schemas<sup>10</sup> for the instances stored in LPG-based DBs. Differently from most works in the literature, that just tried to superimpose OWL to LPGs, losing the expressive power of the latter, we propose to develop a specific ontological formalism for LPGs, so as to take full advantage of their expressiveness.

Finally, we also propose a framework that implements our vision, called *GraphBRAIN* [19], and associated tools for schema and instance handling [20]. In GraphBRAIN, the ontologies and the instances are kept separate from each other (while in OWL/RDF solutions the schema is represented within the graph). This allows to superimpose different ontologies as schemas on the same graph, representing different views on the same data. A GraphBRAIN API acts as a wrapper for the DB to make it available to external applications. All accesses to the DB and operations on its content must pass through the API methods, that given a DB instance and a schema/ontology provides access to the DB so as to ensure compliance with the data schema. To ensure interoperability with standard KR solutions, GraphBRAIN provides import/export functionality from/to OWL for ontologies and/or individuals.

It is worth mentioning that the KB approach to library knowledge representation also enables automated reasoning on the data. With respect to standard OWL-based approaches, specifically suited for ontological reasoning (mostly concerning inheritance handling and consistency checks), our proposal provides a more generic middle layer allowing also additional kinds of reasoning, including:

- Associative, based on graph traversal, naturally supported by graph DBs and their query languages;
- Logical (deduction, abduction, abstraction, argumentation, etc.), e.g. rule- or constraint-based and powered by Logic Programming approaches;
- Instance-based;
- Inductive, to learn high-level concepts or discover (ir-)regularities on the data (including both Machine Learning and Data Mining approaches).

In turn, these approaches may support advanced and personalized solutions to many DL tasks, such as (lexical or semantic) Information Retrieval, Recommendation, Document classification and clustering, Question Answering, Network Analysis, etc. All kinds of stakeholders (researchers, scholars, institutions, hobbyists, casual users) may take advantage of these opportunities.

#### 4. Conclusions: From traditional cataloging to a holistic vision of the data

The current resources of a DL's IT infrastructure are no longer the traditional data; more complete and functional are those derived from a holistic scheme that can emerge from the relationships created from the information on the myriad of books and journals, reports and theses, music and videos, multimedia and hypermedia of all kinds that libraries collect, organize, store and disseminate. After all, in cataloguing, as Hafter already pointed out in 1986, "rules and procedures change" over time and adapt to innovative research practices that give the catalogue a status that can change, just as the technology itself for entering, storing and accessing catalogue data changes [15:11-12].

So far technology has mostly been used to transpose the standard library practices, and little has been done to fully exploit the new opportunities it introduced. To overcome this situation, we proposed a graph-based organization of DL data, based on a technology mixing DBs and ontologies. We also proposed a holistic data schema allowing to store information that is not explicitly present in any of the single documents, but emerges from their direct or indirect relationships. This would enable the use of AI techniques that may significantly expand the effectiveness of data processing, may dramatically improve the exploitation possibilities of documents and disseminate a deeper form of knowledge capable of making users active subjects of technological and social transformation.

In other words, the AI techniques help link the labor of the cataloger in the back office to the labor of the reference librarian in the front office, just as it would to create, organize, store, and use metadata, but also to recreate, reorganize, restore, and reuse it, as the social, organizational, or technological conditions of librarianship change over time [26].

<sup>&</sup>lt;sup>10</sup> E.g., knowing that a Person mentioned in a Document attended an Event in a given Place at the same Time as the Author of the Document might explain why that person was mentioned in the Document, even if this information is not available in the Document itself.

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