Facing Interfaces: Paul Otlet's Visualizations of Data Integration

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The arbitrary division into lines and pages of the book in its present format, does not correspond at all, with the presentation of ideas. (Otlet, 1911, p. 291)

Most historical explanations of interfaces are technological and start with the computer age. We propose a different approach by focusing on the history of library and information sciences, particularly on the case of Paul Otlet (1868–1944). Otlet's attempts to integrate and distribute knowledge imply the need for interfaces, and his conceptualizations are reminiscent of modern versions of interfaces that are intended to facilitate manual and mechanical data integration and enrichment. Our discussion is based on a selection from the hundreds of images of what we may think of as "interfaces" that Otlet made or commissioned during his life. We examine his designs for interfaces that involve bibliographic cards, that allow data enrichment, his attempts to visualize interfaces between the sciences and between universal and personal classifications, and even his attempts to create interfaces to the world. In particular, we focus on the implications of Otlet's dissection of the organization of the book for the creation of interfaces to a new order of public knowledge. Our view is that the creative ways in which he faces tensions of scalability, representation, and perception of relationships between knowledge objects might be of interest today.

Interfaces Seen From a Historical Perspective: Introduction

Most people probably think of computers when reading the term *interface*, but the term was already in use in 1882 (*Merriam-Webster*, Interface). In the traditional sense, an interface is a surface forming a common boundary between objects or phases. In the computer era, the term *interface* has increasingly been used to indicate places where independent and often unrelated systems meet and act on or communicate with each other, such as in the case of human–computer interaction (Wikipedia, Interface). Given the enormous variety in computer interfaces—graphical user, web-based user, command line, tactile, tangible user, text user, object-oriented user, batch, zero-input, and so on—the world of interfaces seems fragmented and the interrelations of the various kinds of interfaces not always clear. This is a preliminary attempt to shed some light on the problem of interfaces as a historical phenomenon.

There have been few historical studies of interfaces. As with histories of the World Wide Web, historical accounts often start with Vannevar Bush (1890–1974). After a brief note on his famous article "As We May Think" (1945), and the Memex, these histories follow the emergence of three types of interfaces in a more or less chronological line: the batch interface (1945–1968), the command-line user interface (1969–present), and the graphical user interface. When this last interface was introduced is not clear. A much quoted account, "Brief History of User Interfaces," puts it in 1981 (Raymond & Landley, 2004). Several authors saw its origins in a device to manipulate visible objects on the screen, the *Sketchpad* that Ivan Sunderland developed in 1963 as part of his MIT doctoral thesis (Myers, 1998). Others chose different devices as representing the birth of the interface, such as Engelbart's mouse of the same year or DATAR, a system that Tom Cranston developed in 1949 for the Canadian Navy to marry radar to digital computers (Akass, 2001; Reimer, 2005). All these historical explanations are technological and start with the computer age. We propose a different approach by focusing on the history of library and information sciences, particularly on the case of Paul Otlet (1868–1944).

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Systematically in his late publications *Traité de Documentation* . . . (1934) and *Monde. Essai del'Universalisme* (1935), and more episodically in various earlier papers, Otlet discussed various modes of integrating and distributing knowledge that imply the need for mechanisms that we now recognize as similar to various current types of interface. Our discussion is based on the analysis of a selection from the hundreds of visualizations of what we may think of as "interfaces" that Otlet made or commissioned in the period of the late 1930s until his death in 1944. These documents are kept in the Archives of the Mundaneum in Mons, Belgium. We will examine his designs for interfaces that involve bibliographic cards, his images of interfaces that allow mechanical and manual enrichment of data, his attempts to visualize interfaces between the sciences and between universal and personal classifications, and even his attempts to create interfaces to the world. In particular, we will focus on the implications of Otlet's dissection of the organization of the book for the creation of interfaces to a new order of knowledge. As early as 1908, Otlet described this as an "architecture of ideas" (as cited in Otlet, 1909, p. 19) and, in 1911, as enabling the creation of "machines to think with" (p. 292; also see Outlet, 1934, p. 100). Our view is that the enormous number of images of what were effectively interfaces that Otlet created in trying to visually get a grip on problems of scalability, representation, and perception of relationships between classes of knowledge objects might be of interest today. We suggest that he can been seen as struggling to conceptualize ideas about interfaces that anticipate modern versions that are intended to facilitate manual and mechanical data integration and enrichment.[1]

From Books to Data (Perceptions of Reality and Documents)

> For written works, a re-arrangement of their contents not along the lines of the special plan of a particular book, but according to the genus and species appropriate to each element does not make for any loss of substance. (Otlet, 1891–1892, p. 17)

Note that Otlet did not use the term *interface*. Necessarily, however, the processes of dissecting and reassembling and communicating the substantive content of books, graphic, and other information carriers that Otlet described as the basis of a new kind of knowledge organization required interfaces. This is suggested most generally in the image in Figure 1. The image captures the general problem for him of representing interconnections or interrelationships of what he presents as elements of knowledge generation and communication. It suggests the complexity of the interface issues with which he wrestled and the difficulties that were created for him of not having available the kinds of digital communications

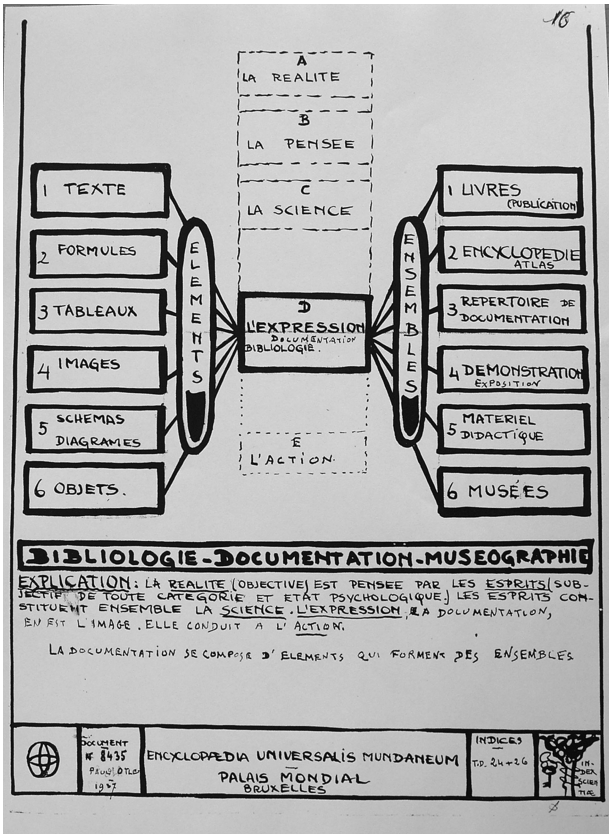

FIG. 1. "Bibliology-Documentation-Museography"—Expression as a double interface between processes of documentation and of thought [June 8, 1937] (Mons, Mundaneum, EUM 8435©).

technologies—along with the concepts of interface that they involve—that we can so easily draw upon today.

In this image Otlet depicts the abstract world of A. reality, B. Thought and C. Knowledge, represented by dotted lines, as involving six kinds of physical elements, represented by bold lines (1. Text, 2. Formulas, 3. Charts and Tables, 4. Images, 5. Schematic Representations such as diagrams and 6. Objects). By means of Expression in Documentary or what he calls "Bibliogical" formats these elements become the basis for six kinds of physical collections (1. Books – publications, 2. Encyclopedias in the form of atlases or collections of charts, diagrams, posters and other kinds of schematic representation, 3. Catalogues or inventories of documents, 4. Exhibitions and demonstrations, 5. Educational materials, 6. Museums). This complex set of relationships is the ultimate basis for the abstract concept of social action (represented by dotted lines). One might explain the image further by saying that informed action requires knowledge of reality that is created by thinking. But knowledge cannot become the basis for effective action until it is represented by documentary elements. To have any permanent existence these must be expressed in documentary or "bibliological" formats that allow them to be assimilated to a range of institutional structures and their different characteristic functions by means of which informed action can be supported over time. In the text accompanying the image Otlet simply says: "Explanation:

[1]For related discussion of aspects of the nature and use of images by Otlet, especially in relation to developments in modern information and communication technologies, see Van Acker, 2009a, b, 2010; Heuvel, 2008, 2009, 2010; Rayward, 1990, 1994, 1997, 2010a, 2010b.

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Reality (objective) is conceptualized by minds (subjective in every category and psychological state). Together minds create knowledge. Expression, documentation, constructs its representation. It leads to action. Documentation comprises elements which form compilations or collections."

He expresses this idea elsewhere in terms of the relationship of the encyclopedia and philosophy that also is represented in this image. They are, he suggested, simply two aspects of the same thing: Reality as a whole is known in terms of analytical detail and synthetic combinations (Otlet, 1911, p. 295). The ultimate objective of the system as represented in Figure 1, then, is to help mobilize knowledge of reality for action. Each stage and level of the processes involved require some form of interface. The major explicit interface in this image is where the documentary elements intersect with their institutional mobilization. This point of intersection is designated "expression." But the descending set of interfaces that presumably are necessary between reality and thought and thought and knowledge and their link to expression on one hand and between expression and action on the other are implicit in the dotted lines in this image. One might re-imagine this static image as a flow chart with arrows indicating the direction of interactions between the various components of the image.

From his first bibliographic writing in 1892, Otlet seemed to have been aware of the problem of interfaces. In his *Un peu de bibliographie* ("Something about bibliography"), he began to explore the idea of how one might obtain more effective access to the knowledge contained in books than the physical format of the book allowed:

> The external make-up of a book, its format and the personality of its author are unimportant provided that its substance, its sources of information and its conclusions are preserved and can be made an integral part of the organization of knowledge, an impersonal work created by the efforts of all. (Otlet, 1891–1892, p. 17)

This idea would return in Otlet's many lectures and publications on the transformation of and substitutes for the book. It would lead to his experiments with textual, visual, audio, and multimedia formats (e.g., Otlet, 1911, p. 28; 1913a, pp. 25–6; 1934, pp. 216–247). Otlet was fully aware that reconceptualizing the book format as the basis for a new kind of collaboratively created form of knowledge representation would require a rethinking of how we are to interact with the processes and techniques of knowledge production and dissemination. This interaction implies what we know as the interface problem.

In a 1911 lecture on the future of the book and of bibliography, Otlet came back to the idea he had first expressed in 1892 and in subsequent publications: "The arbitrary division into lines and pages of the book in its present format, does not at all correspond all with the presentation of ideas" (p. 291). He envisioned the emergence of a future format of the book in which "each intellectual element, in corresponding to a physical element, will create a structure such that any combination of ideas, notions and facts will be possible." He suggested

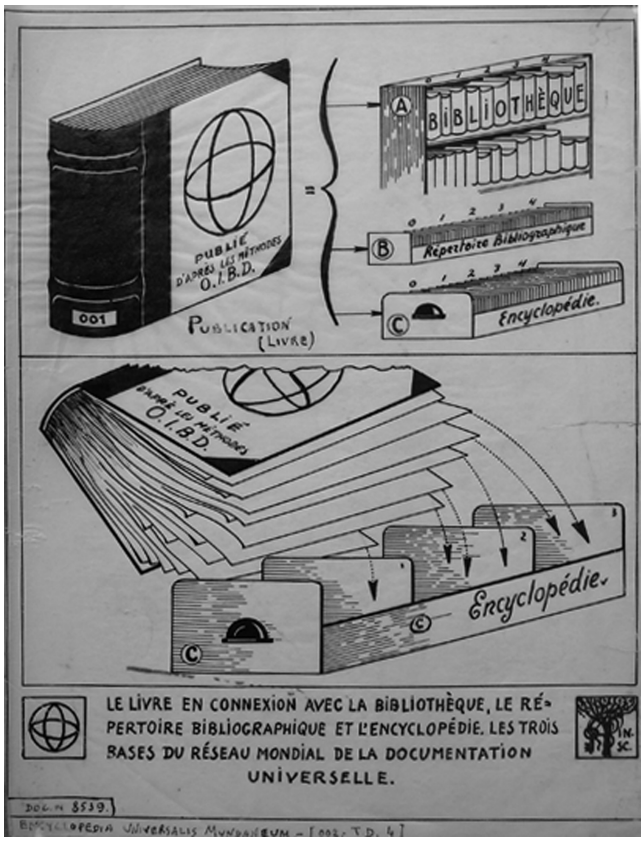

FIG. 2. "The book in connection with the library, the Bibliographic Repertory and Encyclopedia. The three bases of the Global Network of Universal Documentation"—Dissecting the book to create a card system as an interface to the Global Network of Documentation [December 15, 1938] (Mons, Mundaneum EUM 8539©).

that this process can operate in so mechanical a fashion that in the future the book will truly become a machine to think with ("machine à penser;" Otlet, 1911, p. 291). The first step toward this future is to strip each book of whatever is new and adds to knowledge and to collect these information elements separately on cards (Figure 2).

In most of his publications about the future of the book and bibliography, Otlet continued to use the word "Book" (*Livre*), often with an initial capital letter to designate the new, ideal form that he was envisioning. An important step both terminologically and conceptually was his introduction of the concepts of "the document" and "documentation," which he invested with extended meanings. We suggested elsewhere, following Foucault, that these concepts represent a new discursive formation, a new way of talking about something (Rayward, 1997). A document is whatever expresses an idea, a thought, or an impression. It can vary from the conventional written and printed document to any form of representation, including images and artifacts of various kinds. Documentation for Otlet involved a complex of processes for the analysis, synthesis (what he also referred to as "codification"), and distribution of information through a network. The last at its most grandiose he called the "Global Network of Universal Documentation." Documentation, Otlet (1907) observed,

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"is not limited to recording information but will allow its automatic retrieval at any moment it is required; [documentation is] a vast intellectual mechanism designed to capture and condense fragmentary and scattered information and to disseminate it wherever it is needed" (p. 11).

His view of processing information led Otlet to formulate what he called the "Monographic Principle," according to which documents are dissected into their constituent informative components or elements. Scholars would work together, assisted by machines, to carry out the complementary operations of analysis and synthesis by which these elements could be extracted, recorded on cards, recombined, and ordered mechanically. The cards would be arranged by the Universal Decimal Classification system (UDC) that Otlet and his colleagues developed from the Dewey Decimal Classification System. In effect, Otlet described the creation and use of a database via the techniques and systems of documentation—the database essentially is a new form of the book (Rayward, 1994).

Otlet envisaged not only new ways of organizing knowledge to create a special kind of database but also new ways of communicating or interacting with the database. In a 1908 lecture entitled "La function et les transformations du livre" at the Maison du Livre in Brussels, Otlet explained that radio might be substituted for the book as a means of providing access to information. He suggested that this would lead to the development of on-demand wireless transmission ("transmission à distance sans fils"), the "irradiation" of documents held in central institutional repositories whose creation he was envisioning. These centers would be "Multiple places for reading and listening around the world, all linked to the same universal network," which would "permit the diffusion of knowledge without any sort of limitation" (Otlet, 1909, pp. 29–30). But for Otlet, this network of institutions and individuals also was an instrumentation for the production of the knowledge to be incorporated into the central database. In the late 1930s, he designed what we would consider to be a multimedia workstation where individuals could interact with the universal network of documentation, in what seems to us a manner not dissimilar to that of a Web 2.0 (Heuvel, 2009a; Heuvel & Rayward, 2011; Rayward, 2010a).[2]

Otlet's Experiments With Interfaces: Toward a Typology

Information Object or Thing as Interface

Noting the vast increase in the volume of publications over the centuries, Otlet suggested that this has led to a new form of reading, of consultation. "Once," he said, "one read; today one refers to, checks through, skims. . .. Works are referred to, that is to say, one turns to them to ask for a reply to very specific, specialized questions" (Otlet, 1903, p. 79). Otlet realized that this function of "skimming" in a new knowledge regime in which information in books and documents is continuously analyzed into manipulatable chunks according to the monographic principle would lead to an enormous increase of cards and sheets containing these data. But it also would require new ways of linking the chunks of information and of retrieving them. In effect, collective knowledge production of the kind he was envisioning would result not only in a massive increase in the size of the database but also would place a burden on the technical capacity of individual cards from which the database was constituted to provide access to information. He suggested that the answer to this problem is essentially a new form of the Book, the search for which he believed was actually under way (Figure 3)—presumably as much by himself as anyone! This new format

> . . . will be based on the analytic transcription of information ("faits")[3] on cards which will allow the arrangement of multiple headings by means of tabs ("saillies") on each side of the cards (Figure 3a). It follows that, if the headings are numerous, the tabs will be spread out along all the sides of the cards. To increase the number of sides, one might well abandon the rectangular form of the card and adopt a polygonal form, an octagon for example. For sorting and systematically selecting the ideas that have been classified hierarchically, the cards are suspended from their centre. The Book as a structure of cards thus takes a quasi-circular form and can rotate. This means that searches by manual consultation could actually be replaced by mechanical selection. Statistical machines now select and count thousands of individual cards an hour without human intervention.[4] An adaption of the latest type of these machines corresponds very happily to the desideratum of a mechanically consultable book. It does this so well that its structure, governed by its function of creating an integrated and permanent record, constitutes a Book—for it is still a book—that has abandoned the traditional form of linear text arranged according to a unique plan. It has been transformed in some way into a body with several dimensions, as many

[2] A description and analysis of this is in preparation, W.B. Rayward & C. van den Heuvel, "Mondothèque: All the knowledge of the world at one's fingertips: An analog prototype of a scholar's work station." Van den Heuvel and Rayward together with graphic designer Janet Armstrong produced a poster for Katy Börner's "Places and Spaces: Mapping Science Project" representing the Mondothèque in a global internet (Heuvel & Rayward, 2011).

[3] Otlet commonly used a range of information-related terms such as "données," "faits," "reseignements," "connaissances," "resultats," and "informations," all of them, including the last, in usually the plural in contexts where they often seem to express distinctions without much difference. Commonly translated as "facts," "faits" is the most problematic conceptually, and it seems more appropriate to translate it as "information" unless the context suggests that the idea of "facts" seems specifically to be meant.

[4] Such statements suggest that Otlet was aware of the Hollerith tabulating and sorting machines that had been used for the 1890 US Census. He calls them "machines á stastistique" and refers to them again, for example, in his, "Transformations of the bibliographical apparatus of the science," (Otlet 1918 p. 156). However it seems that he is not referring in what he proposes here to punched cards in that "*saillies*" refers in its various meanings and usages to some form of protuberance which we have here translated tabs. Otlet gives and extended description of the tabulating and sorting machines of Hollerith (whose Tabulating Machine Company of 1896 was to transition into IBM) and James Powers (whose Accounting Machine Company of 1911 was to become Remington Rand Tabulating Machine Company) in the general section on "Equipment: Machines for Intellectual Work" of his *Traité de Documentation* (Otlet, 1934, pp. 387–388; Norberg, 1990).

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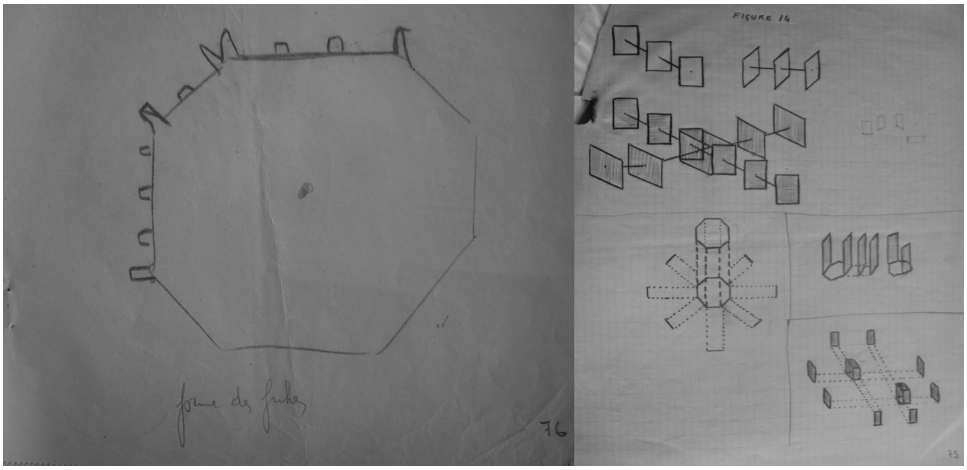

FIG. 3. Otlet's experiments with linking bibliographical cards multidimensionally (a, b) (Mons, Mundaneum EUM 9 n. 75+76©).

> dimensions as headings such that different searches using the same graphic elements on the cards are possible. (Otlet, 1911, pp. 290–291)[5]

Otlet thus described a new process of flexible information search and retrieval that allows for multiple points of contact between cards and the information inscribed on them according to the changing and complex interrelationships of subjects, which for him are encoded in the notation and combinatorial processes of the UDC. This is not dissimilar to Manovich's idea of the database as new cultural form that Jack Andersen has taken up. The database is a new cultural form because of its "way of representing the world as a list of items and not as a narrative". The user's experience of the database is quite different from reading a book or viewing a film in which linearity and sequence have traditionally been paramount. The new computer-based media appear as databases because "users can perform various actions with them like viewing, navigating and searching" (Andersen, 2008, pp. 270–271). Figure 3b is a sketch by Otlet in which he was attempting to visualize how cards might be connected to reveal complex, multidimensional conceptual relationships.

His experiments with polygonal index cards and card stands are examples in which information objects become physical interfaces in a network of things.[6] This solution was impractical for many reasons, but did not prevent Otlet from continuing his quest for multidimensional representations of documents and metadata.

Cycles of Operations in Documentation and Batch Interfaces

For Otlet, the two most important operations in knowledge production were analysis and abstraction or synthesis. The information chunks that result from analysis have to be mechanically or manually pieced together to create an optimal and new synthesis. Appropriate interfaces are necessary if this process is to be implemented. Several of Otlet's images drew on industrial factory metaphors to suggest the nature of these interfaces (Heuvel, 2008, p. 133, Figure 7; 2009a, pp. 218–219, Illustration 3). In Figure 4 Otlet uses the powerful image of a Bessemer converter. This was a major innovation in the nineteenth century that allowed the creation of steel from pig iron and thus development of the technologies of modernity that depend on steel ranging from wires, cables, railway lines and locomotives to steel girders for bridges and skyscrapers such as the Eiffel tower. In Otlet's image all sorts of documents – books, periodicals, newspapers, legal documents, patents – are poured as raw materials into the mouth of the converter. After processing the converter is pivoted on its axle so that what is now information refined of all dross can be poured as facts into the ten molds that reflect the ten major categories of the UDC but that also function as railway trucks. The locomotive drawing them will carry the purified substance of knowledge from the factory into the world for use. The text at the base of the image reads: "The Powerhouse of Documentation: extracting pure matter useful for civilization from mountains of documents." This same idea of processing the content of books and tipping it into the trays of the encyclopedia can also be seen in Figure 2 above.[7]

The implication in this case is that the system managing the documentary operations can be described, to use Jacob Nielsen's terms, as a function-oriented, document-oriented file system. As such, it meets his three conditions for such a system: The information is disjunctive, but forms coherent units; the units are classified according to a single hierarchy; and finally, the units have single names (Nielsen, 1993, 1996). The grinder in this image can be compared to a batch interface, a noninteractive interface in which all the details of the

[5]As mentioned earlier, the use of the capital letter for "Book" (Livre) in this, as in a number of other papers of Otlet, is intended to indicate that he is no longer referring to the traditional codex form of the book but to its new form as a kind of database created from separate cards or sheets.

[6]This is an interesting variation of Michael Buckland's (1991) idea of information as thing.

[7]For a discussion of this striking image, see Heuvel (2008, p. 133, Figure 7). It also was used as the design for the cover of Rayward (2008).

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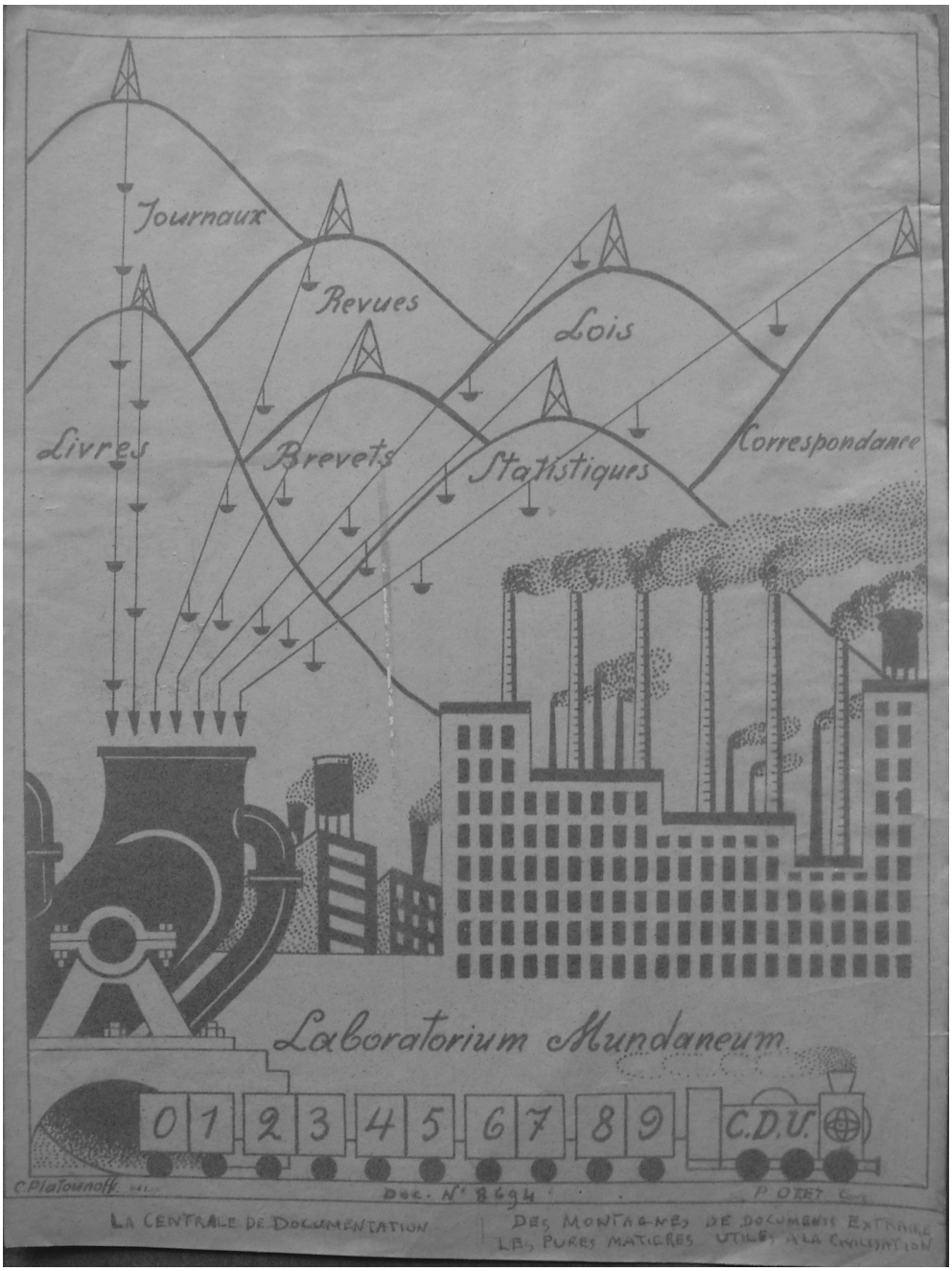

FIG. 4. Laboratorium Mundaneum: Powerhouse of Documentation. C. Platounoff on commission of Otlet [December 28, 1937] (Mons, Mundaneum EUM 8694©).

batch job are specified in advance and where the user receives the output when all the processing is done. The computer—comparable to the knowledge factory, with its smoking chimneys in the background of Otlet's image—does not prompt for further input after the batch processing has started.

Object-Oriented User Interfaces and Navigating Through Knowledge Classes

Modern object-oriented graphical user interfaces are different from traditional function-oriented user interfaces in which the user specifies first functions and then arguments (such as delete–file) in that, first, they provide access to the object of interest to enable users to subsequently operate upon it (Nielsen, 1993). We may well think of Otlet's UDC system as an example of a function-oriented user interface. A UDC code derived from the UDC's main tables and auxiliary tables is first provided for a specific information chunk. Other actions can follow, such as, for example, navigating through the hierarchical subject arrays and other relationships expressed in the codes. Otlet depicted this in an image that represents the administration of the city of Brussels in the

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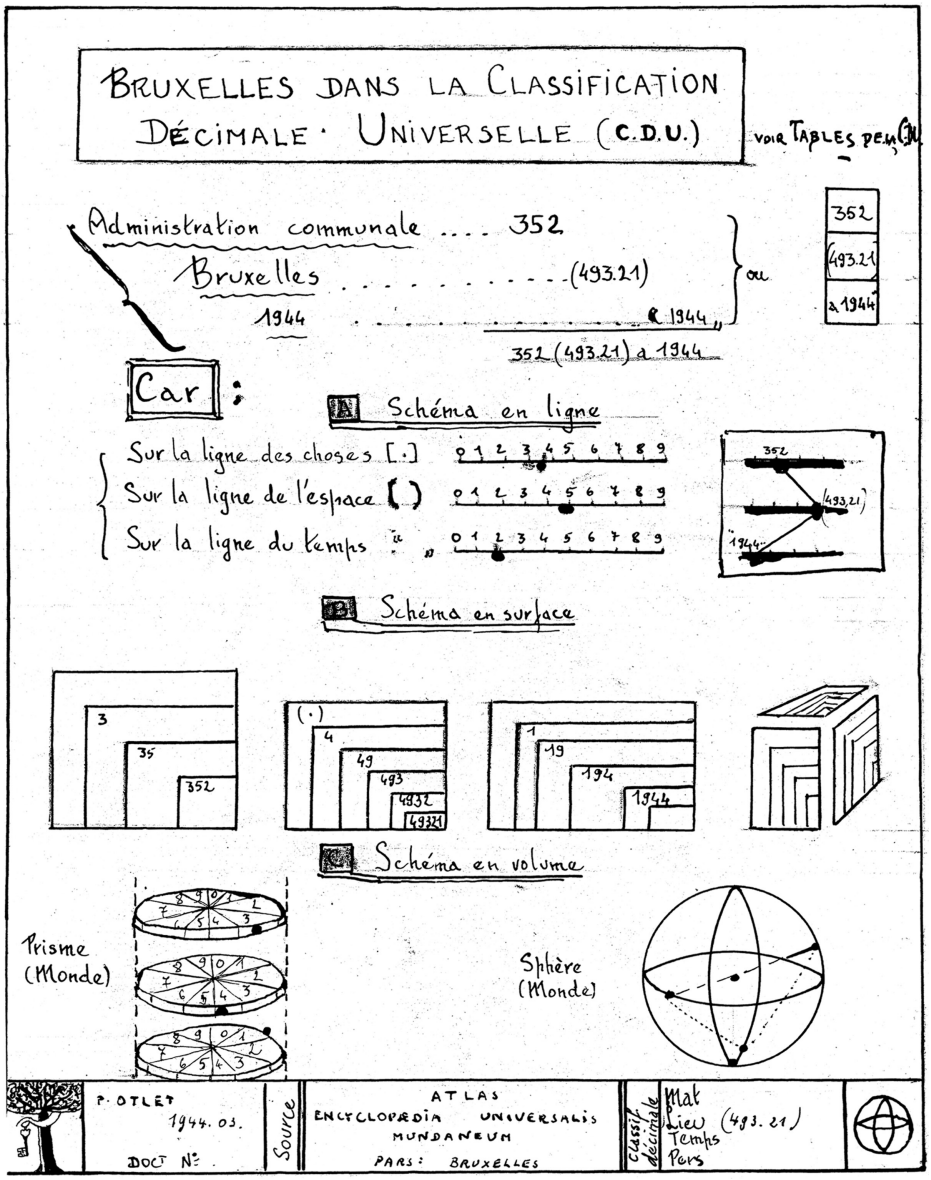

FIG. 5. Brussels in the Universal Decimal Classification (Example of the Communal Administration of Brussels in 1944) [March 1944] (Mons, Mundaneum©).

year 1944 by means of a code comprising strings of decimal numbers (Figure 5).

In this image, the UDC number for the Communal Administration of Brussels in 1944 also can schematically take the form of points in lines representing matter, space, and time. It also can be represented schematically on two-dimensional surfaces that can be combined into a three-dimensional cube, each subordinate rectangular element labeled with its number, thus illustrating the super- and subordinate relationships incorporated into the UDC expression. Finally, its elements also can be located schematically in two different three-dimensional volumetric representations of the world. These multidimensional representations were not only alternative ways to visualize the workings of the UDC but also anticipated new ways to navigate through the idiosyncratic order of knowledge that Otlet proposed.

Graphical User Interfaces and Otlet's Visualization Toolkit and Visual Language

Otlet experimented with a graphic user interface in a manner not dissimilar to the Sketchpad mentioned earlier that Ivan Sunderland (1963) developed to work with geometrical figures on the screen. Otlet thought of a toolbox of lines and figures that would allow users to make their own visualizations. In his *Traité de documentation* of 1934, Otlet proposed a formatting tool that is comparable to Word and

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Clip Art. It consisted "of curved and broken lines, of polygonal and circular forms, all the basic units needed for manually composing diagrams, figures and simplified drawings (Otlet, 1934, p. 390).

Otlet was particularly interested in visual languages that were able to express semantic meanings independent of natural languages based on text, but that could provide interfaces to the content of textual and museographical collections. His earliest views of the UDC were a step in that direction in that he believed that it could form a kind of universal language of numerical codes, a veritable new language whose . . . [figures] translate ideas absolutely common to the entire scientific world and express them in universally understood signs—numbers. . . . the Decimal Classification actually constitutes an international scientific language, a complete system of symbolization for science . . . (La Fontaine & Otlet, 1895–1896, p. 34). Otlet (1896) even considered the classification as able to become a "veritable pasigraphy able to interpret by numerals grouped into factors having a separate and permanent meaning all the nuances of ideologico bibliographic analysis" (Couturat, 1907; Guérard, 1979, p. 59).

But his interest in images, of creating reconstructed text and image files to form new kinds of encyclopedic collections that would complement and extend the bibliographic apparatus with which he was first concerned (e.g., the Universal Iconographic Repertory and the Universal Encyclopedic Repertory of Files; see Rayward, 1997, 2010a), led him to seek new approaches to accessing knowledge based on new kinds of visual representation. In 1912, for example, Otlet and the Scottish sociologist and town planner Patrick Geddes proposed the preparation of an *Encyclopedia Synthetica Schematica* in the form of charts and diagrams. The schemas and diagrams were to become a "graphical language that would permit the expression of general or abstract ideas more completely and more definitely" than could words (Heuvel, 2008, p. 134).

Though nothing came of this proposal, it is important because it represents a formalization of ideas already being developed separately by the two men. It reflected their increasingly strong belief in the need to go beyond the traditional book format and the linguistic modalities of representation that it entailed. Geddes' idea of an "Index-Museum" and his paradoxical relationship to text which was similar to Otlet's is discussed in Chabard (2008, pp. 107–108) and Van Acker (2010, pp. 181–183). Very early on, however, Otlet suggested that it was necessary that knowledge be increasingly "condensed into enormous integrated documentary encyclopedias" in the form of "repertories, cards and files" as a basis for a "vast permanent network of intellectual exchanges" (Otlet, 1909, p. 26; also see Rayward, 2010a). He believed that the book in the future would not only draw on language that has become "more supple, easier to understand, more effective" but also will draw on "other forms of representation of ideas than text: "illustrations, diagrams, schemas, a much improved symbology of ideas" (Otlet, 1909, p. 27).

These ideas were taken a step further in 1910 when Otlet and his colleagues set up an International Museum. Initially, the museum was explicitly designed to exhibit materials related to the scholarly and other congresses being held at the Brussels World's Fair of 1910 and that were to culminate in the World Congress of International Associations at which the Union of International Associations was formed (Musée International, 1910, pp. 20–21). The objective was to create evocative representations of abstract ideas. The notion of "evocation" was important. Evocation involved assembling broadly based representations of abstract ideas that in effect could only be "seen by the eyes of the mind" (Otlet, 1913b, p. 5). Thus, it would be "an International Museum of diagrammes, cartograms, models and typical documents" (Office Central des Institutions Internationales 1911, p. 13). The displays were described variously as involving small-scale models, plaster casts, marquettes, facsimile publications, specimens, charts, tables, graphs, diagrammes, outlines, engravings, drawings, photographs, and posters among others (Musée International, 1910, p. 23; Union of International Associations, 1912, p. 107, Otlet, 1913, p. 7). They were to provide the much needed "improved symbology of ideas." The International Museum was thus to be "a museum of ideas. . . ." It left to other museums the responsibility of collecting and preserving rare and precious objects (Union of International Associations, 1912, pp. 107–108). Otlet (1928) coined the term "Idearium" (p. 10) to describe it and suggested that the new kind of encyclopedic museum he was advocating could be thought of as a "cosmoscope" that will allow "one to see and understand Mankind, Society and the Universe. Formed by the combination and synthesis of all the factors of past and present progress, it will give a vision of the future" (Ducheyne, 2009; Otlet, 1914, p. 117).

As Otlet began to explore the educational value of the new museum, the idea of reproducibility led him to the notion of "Atlas," which represented an extension of the English idea of "atlas" to include collections not only of geographic maps but of prints, reproductions of tables, and graphic documents generally that are attached to a work to aid understanding.[8] Otlet then began to develop the never-completed, never-published *Encyclopedia Universalis Mundaneum* (EUM), which he worked on till the very end of his life in 1944 (Van Acker, 2010; Heuvel, 2008). Experiments were undertaken in the late 1920s to produce an Atlas of Universal Civilisation in various formats, including microfilm (Otlet & Oderfeld, 1929). It also was at this time that Otlet's museological ideas, especially about the reproducibility of museum displays, strongly influenced those of Otto Neurath, a leading member of the Vienna Circle of Logical Positivists who was much concerned with finding new approaches to the idea of encyclopedia and to display methodologies that would speak directly to ordinary people attempting to grasp complex, descriptive, statistical phenomena. While an initially intense collaboration between Neurath and Otlet soon seemed to lose

[8]Dictionnaire de l'Académie française huitème édtion, Version informatisée, "atlas." Retrieved from http://atilf.atilf.fr/academie.htm

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impetus, Neurath developed a highly successful methodology based on standardized, easily reproducible charts and panels in which statistical and other data could be expressed visually with great simplicity and clarity. He invented for this purpose what is called the *Vienna Method of Pictoral Statistic* or *ISOTYPES* (Van Acker, 2010; Hartmann and Bauer, 2006; Vossoughian 2008a, 2008b), and Otlet on occasion used this method in charts prepared for the *EUM*.

For Otlet, the relationships between museum, library, encyclopedia, and classificatory language were complex and interdependent, such that each became a point of entry or interface for the other. Otlet stressed that responses to the evocative displays of the museum involved intellectual and social processes different from those involved in reading in a library, but that one in a sense entailed the other. Equally, it is clear that for Otlet, the charts, tables, posters, and so on that were used to create the *EUM* derived in part from the exhibits being prepared for the International Museum, but also were to become important components of its displays. The *EUM* became a visual, highly schematic interface to, and in a sense, a substitute for, the museum itself and for the world of knowledge locked away in the collections of libraries. Van Acker (2010) considered that Otlet wanted to redefine the meaning of encyclopedia to become a "graphic and scenographic construction" that he suggested was midway between the medium of the book and that of the museum (pp. 179–180).

Notes and Nodes: Otlet's Network of Documentation, the UDC, and Web-Based User Interfaces

For Otlet, the interface that did more multidimensional work than any other was the UDC. The potentially complex subject codes of the UDC served as multiple interfaces to subject knowledge in various formats. They ordered the cards of the Universal Bibliographic Repertory, and it was recommended that search statements be formulated as UDC numbers. The plates, drawings, and schemas of the EUM were nearly always given these codes. The objects in the International Museum were classified by them (Musée International, 1910, p. 23). We have argued that the UDC might be considered as the basis for a kind of early paper-based hypertext system (Rayward, 1994). We already noted Otlet's idea that the UDC could become the basis for a pasigraphy, a new kind of artificial or documentary language. But the UDC may be considered to play an even more important part in Otlet's conception of a fundamental, but universal, mechanism for knowledge representation and access: the Universal Network of Documentation.

Note that Otlet was interested in distributed authorship. The idea is rooted in his concept of the cooperatively compiled universal book present in to his earliest thinking about a "science of the book and of documentation" (Otlet, 1903). The universal book was to be a dynamic, continuously growing entity receiving additions in all sorts of formats by scholars throughout the world. But the ideas, findings, results, and so on that would be identified, extracted, and recorded according to the "monographic principle" had to be linked together in a controlled and controllable way to create the scientific synthesis that was the objective of the process (Otlet, 1913a). The UDC played a crucial role in the standardization and calibration necessary for the functioning of the knowledge infrastructure, the Universal Network of Documentation, that Otlet proposed for this purpose. The UDC notation reflects the order of highly detailed subject tables. It arranges subjects or topics in a static array of classes by means of often long and complex codes formed from decimal numbers. But also by a process of number compounding based on the auxiliary tables of the common subdivisions, it allows for the detailed subject specification of the content of individual documents in terms of such facets as place, language, time, different points of view, and the physical format of the documents. Each of these elements is indicated by a particular sign (=, +, /, etc.), with its own prescribed place in the structure of the UDC expression that encodes the subject matter of a particular document. For example, 663.4(493)(075) = 112.5 Brewing industry in Belgium – textbook – in Flemish (UDC consortium) or 526.9 : 336.211(431)"1927" = 3 (Guide to Prussian cadastral surveying in 1927) (Rayward, 1994, p. 242) (Rayward, 1994; and especially UDC Consortium, 2011). It is possible to see these connector signs as nodes to which scholars could link their notes, assisted or not by machines to update the Universal Network of Documentation. In that sense, these connector signs might be considered as interfaces to producers of knowledge within an infrastructure that is not dissimilar to what Börner (2006) called a *semantic association network* in which the heart of scholarly activity becomes a form of enriching nodes (p. 198; Heuvel, 2009a, p. 225).

Otlet struggled to conceptualize and find ways of implementing his vision of data enrichment by scholars. How were contributions of new information to be made through the universal documentary network to the centralized database? The system Otlet devised for the Universal Bibliographic Repertory of different-colored divisionary cards and tabs in a UDC file (each also showing its special sign of association) parallels recent software development that seeks to differentiate forms of expertise in Web 2.0 by coloring the provenance of the links of the various contributing authors. Otlet's system highlights the location and establishes the order of numbers derived from the UDC's auxiliary tables—and hence the contributions that would be linked at these tabs. It suggests an interesting typology of different sorts of possible data enrichment. There is a group of categories related essentially to the documentary forms in which data are transmitted. A more interesting group of categories is specifically concerned with what we would think of as data enrichment. These involved (a) additions of new subject data (essentially increasing the complexity of the underlying data), (b) additions of analyses (new approaches or observations related to the existing data), (c) additions of points of view or interpretations of the existing data, and (d) additions of new connections or relationships to other data (Heuvel, 2009a, 2009b).

Otlet's idea of a Universal Network of Documentation as an infrastructure for "the registration of ideas" in all sorts

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of documentary formats comes close to the definition of the Semantic Web by the World Wide Web Consortium (W3C) as a "Web of data." Moreover, the W3C described the vision behind the Semantic Web as extending "the principles of the Web from documents to data. Data should be accessed using the general Web architecture using, e.g., URI-s; data should be related to one another just as documents (or portions of documents) are already"(Heuvel, 2009a; W3C, 2001). The high degree of transparency in protocols for updating the UDC and the visualization of the provenance of annotations also relates to current discussions of the role of authority in distributed authorship, such as the contributions to the Semantic Web by the Linking Open Data Community.

Otlet's Concept of Hyper-Documentation and Multisensory Interfaces

Otlet eventually suggested that documentation evolves through various stages. The last and ultimate stage involves the "Sense-Perception-Document" which is the basis of what he called "hyper-documentation." "Sense-perception-documents are fusions of things and ideas. Visual and sound documents are complemented by tactile, gustatory, olfactory and even other kinds of documents. At this stage what is unknown and imperceptible will become known and perceptible. . . ." Otlet (1934, p. 429) suggested that even what was hitherto irrational, intransmissible, and thus neglected, but that had led to the revolutions and uprisings of the day, ". . . will find its expression in ways that still cannot be anticipated. And this will truly be the stage of Hyper-Documentation" (p. 429).

In this way, Otlet introduces a different and unconventional notion of document creation and understanding that would require, as yet even for him, unimaginable kinds of new interfaces. Unsurprisingly, these were never realized, though we see him struggling with the idea in various sketches of human beings who are apprehending multimedia documents via the five senses (Figure 6). And yet, in attempting to link the senses with documentation as described earlier, one might argue that Otlet is in effect adumbrating current explorations of synesthetics and recent experiments with multisensory interfaces. An example of this is Multi User Laser Texture Interface, which allows synesthetic experiences and the manipulations of objects in a three-dimensional computer-game environment called the "Library."

Interfaces to the World: Problems of Scalability, Representation, and Visibility

For Otlet, the ultimate problem that he struggled with endlessly was always how to provide access to knowledge of the world in the entirety of that knowledge, the universe of knowledge, even to the knowledge of the unknown, imperceptible, and irrational. He explored numerous representations of the structure and relationships of elements of knowledge of the world. His book *Monde* (1935) is essentially

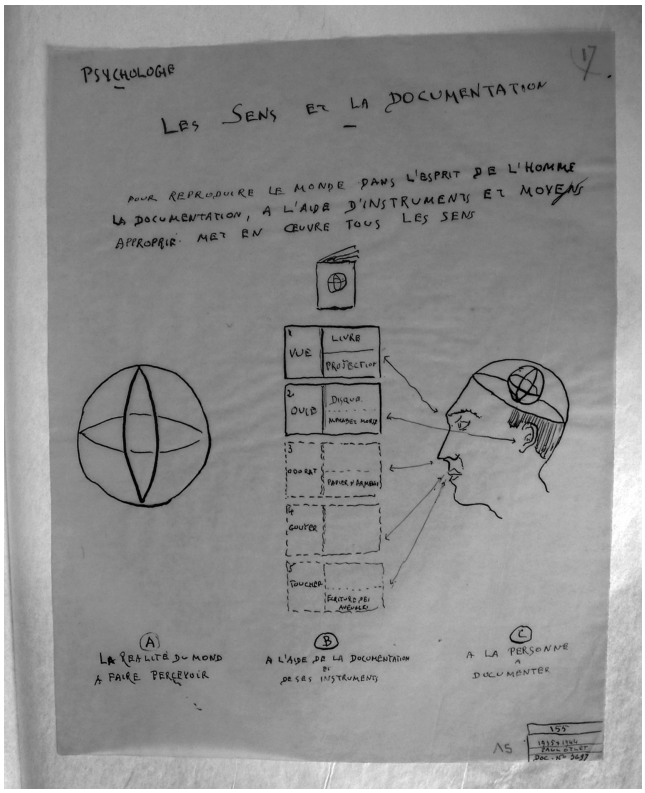

FIG. 6. The senses and documentation. Two dates 1935 and 1944 (Mons Mundaneum EUM 3697©).

an explanation of a descriptive formula that he created to encapsulate it (Figure 7).

His figures of the Sphaera Mundaneum consist of interlocking spheres (Figure 8). They proceed from what was external and perceptible—nature, man, society, divinity, space, and time—to the knowing, feeling, acting self, le Moi, but also divinity and even the unknown and mystery. This in turn reaches out to the wider elements of reality, creating synthesis, harmony, and organization by means of expression as represented by the arts and technologies of documentation.

Note that Otlet attempted to capture the idea of a mechanism that would reveal Mankind, Society, and the Universe to the understanding in the Cosmoscope, a kind of metaphorical instrumentation of the Sphaera Mundaneum. At first sight, it seems that Otlet's idea of the Cosmoscope, by which the relationship between macrocosm and microcosm becomes visible and through which all aspects of reality (including the unknown) have a clear space, is coherent. However, a close reading of *Monde* revealed a growing interest of Otlet in contemporary developments in physics that inevitably leads to a form of tension within his all-encompassing system. He refers to the contradictions that have arisen between the theory of relativity and the quantum theory, and it becomes clear that he saw similar tensions reflected in his own universal knowledge system (Heuvel & Smiraglia, 2010; Otlet, 1935, pp. 16–31). Whereas in his visual representation of the world he expresses a clear-cut distinction between time and space, giving them separate classification numbers both in the

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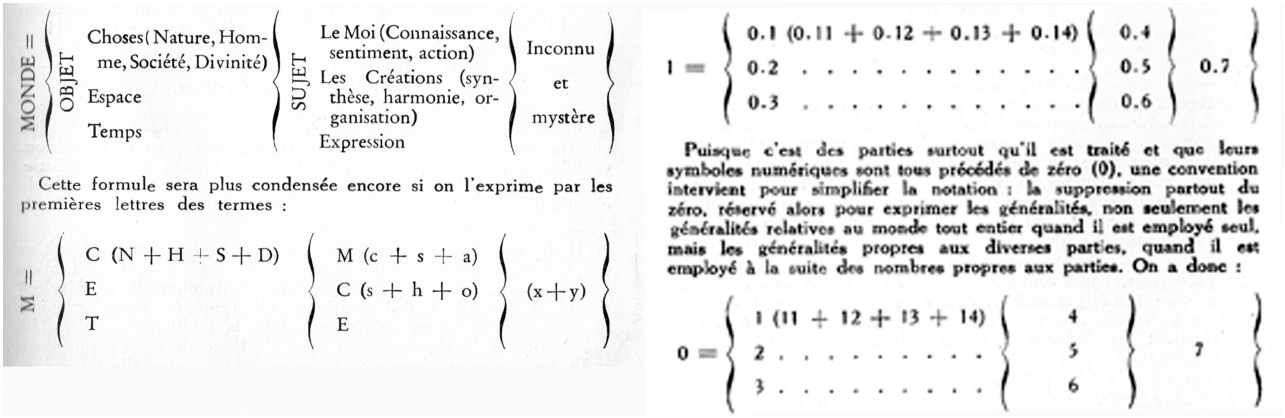

FIG. 7. Otlet, *Monde*: Formulation of an equation as an interface to the world (pp. XXI–XXII) (Mons Mundaneum©).

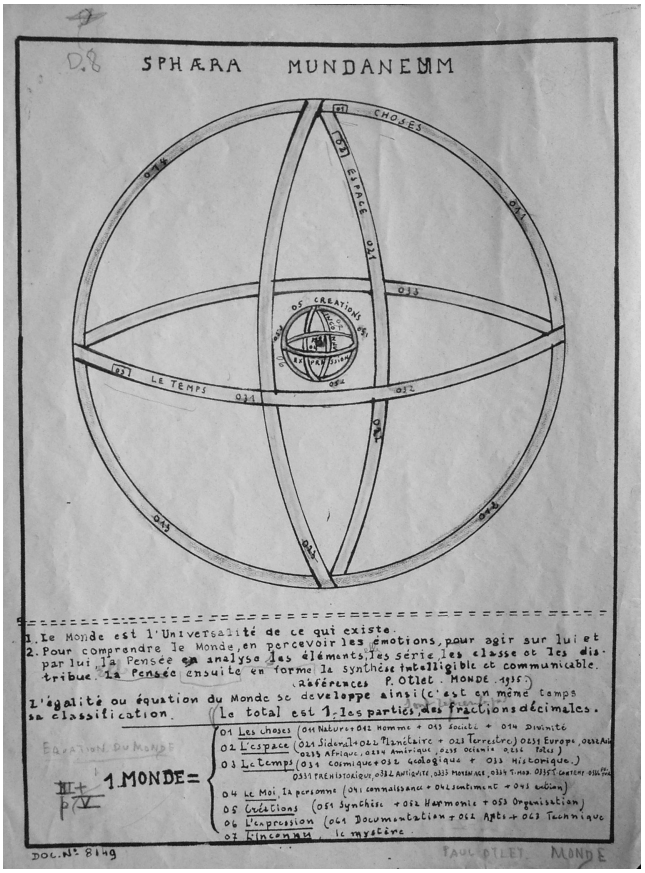

FIG. 8. Otlet: Sphaera Mundaneum [July 31, 1937] (Mons, Mundaneum EUM 8149©).

UDC and in such representations as the Sphaera Mundaneum, he stated in the text of *Monde:* "Substance, Movement, Space and Time are the four most fundamental categories that for us constitute the World. These categories are not separable but simultaneous" (Otlet, 1935, p. VI). For Otlet, matter–energy and space–time can no longer be split into clear-cut categories. He also seems to be aware of the problem of scalability: "The laws applicable to macro-physical objects are not applicable to micro-physical objects" (Otlet, 1935, p. 30). However, he suggested that this fundamental scalability problem of physics can be solved by mathematics. Mathematics is not merely a "tool of powerful condensation" (Otlet, 1934, p. 428) that enables high levels of abstraction but it has become a means of elaborating concepts that not only cannot be translated into any other language but are otherwise imperceptible (Heuvel & Smiraglia, 2010; Otlet, 1935, p. 30). But in applying "mathematics" to his own thinking Otlet simply replaces verbal concepts with a numerical notation such as that of the UDC to improve data integration.

Otlet's "Interface as Thing" and Data Integration

In discussions of data integration, there is often an illusion that data deriving from various sources and with different meanings are commensurable. Issues of the quantity, but especially of the heterogeneity, of the data to be integrated make such views problematic. Ziegler and Dittrich (2004) made clear how complex the practice of data integration actually is. Although we might believe that we are interacting with a single information system in which all the heterogeneous components have been connected seamlessly into a unified, homogenous whole, in reality there may well be an underlying set of structural, architectural, and semantic integration problems that is not apparent to the user but that affects access to the data in a variety of ways. Anyone who scrolls through Google images for visualizations of data integration will recognize many two-dimensional diagrams, flow charts, and symbolical representations of jigsaw pieces that seem to fit well together. Even when three-dimensional volumes are used to symbolize containers of data, they are smooth cylinders connected by arrows representing smooth exchanges within the system. However, the character of integration problems can be assessed properly only if the problems become visible at the fringes of the system, at the interfaces where heterogeneous components meet.

Most of Otlet's three-dimensional knowledge representations show interfaces between subsets of data and a larger whole, or vice versa. These are not dissimilar to data integration models expressing the relations of the part to the whole

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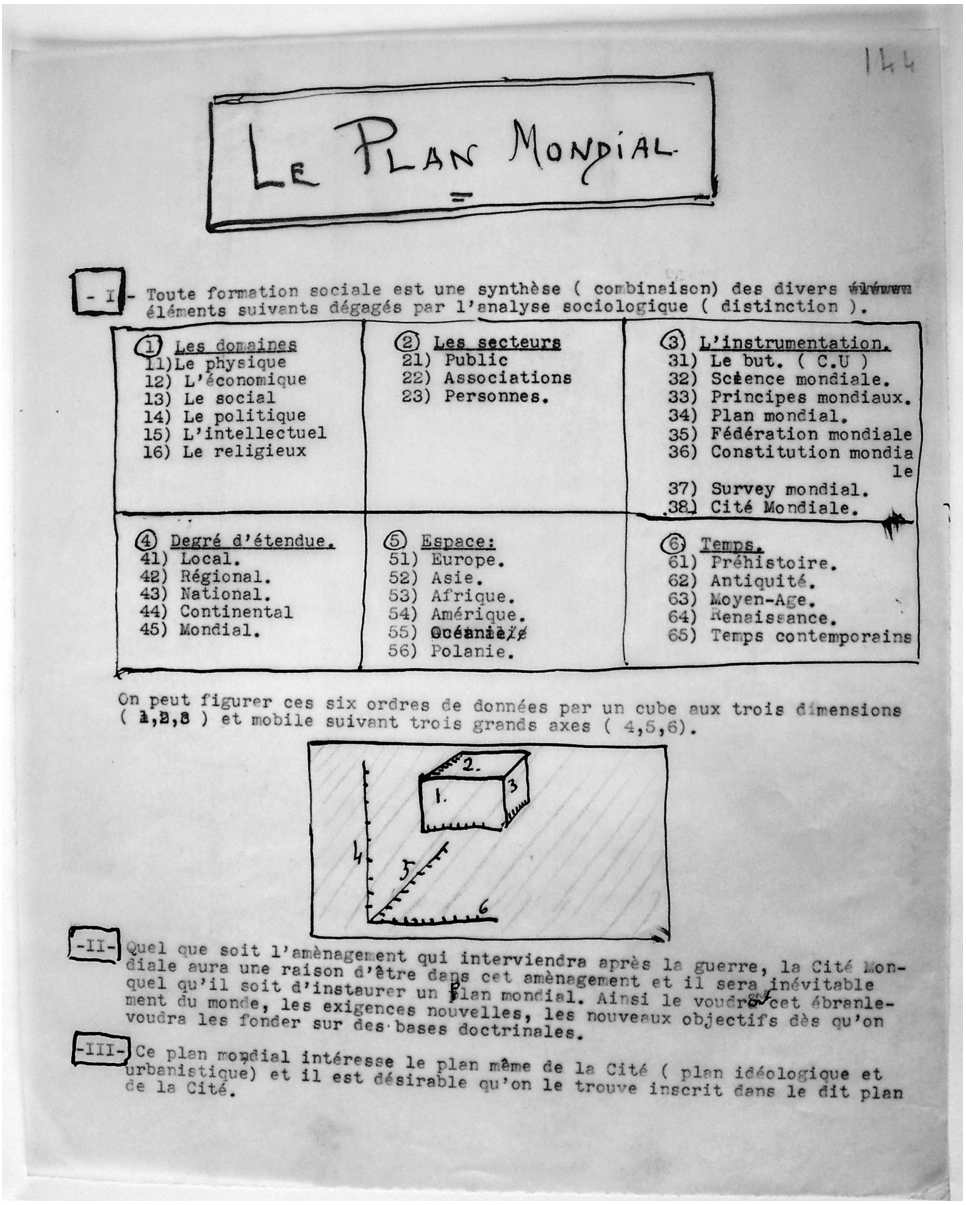

FIG. 9. "Le Plan Mondial"—A design for a dynamic interface to the plan for the world (Mons, Mundaneum©).

and vice versa, such of the Global as View and the Local as View approaches (Wikipedia Data integration). Limitations in visualizing the connections between the various components of knowledge objects in this visualization of the World Plan (Figure 9) suggest new research questions about, and insights into, the design of interfaces.

One of the problems of an image such as this in which Otlet crams so much detail that clearly continues a long and complex process of ratiocination is that what it is designed to do becomes unclear. Listed in the category "Instrumentation," for example, is the World Plan, the development of which is what the image as a whole is presumably designed to illustrate. Nevertheless, this image is distinctive in that it is an attempt to represent dynamic category relationships. The three visible sides of the cube represent (a) the existing domains of knowledge, (b) the organizational sectors involved in the production and management of knowledge (the public, individuals, associations), and (c) an instrumentation of processes and institutions to be integrated into the plan (a universal classification, globally accepted principles, world knowledge, a world plan, a world federation, a world constitution that presumably would govern the federation, a global survey, and a World City). Otlet explicitly indicated that he envisions the cube as a mobile, three-dimensional object moving along three axes: x (administrative or organizational level), y (space), and z (historical time). From this figure, we can deduce that as the cube moves, relationships between the data on the three visible faces of the cube on one hand and the data on three axes on the other hand would change. It is interesting that Otlet listed only six

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major domains of knowledge and not the "decimal" 10 general classes of the UDC that he projected onto his spherical representations. The fact that he intended that the cube should move, but was limited by the two-dimensional static qualities of paper, adds to the difficulties of representing the relationships between what is represented on the cube and the axes along which it is to move.

These limitations suggest potentially creative "what-if" scenarios. What would happen if we translated Otlet's design for a mobile cube into a modern computer simulation where the user can navigate through time, space, and contextual information with simple movements of the mouse? What would happen if Otlet's axes were smooth-gliding scales instead of subdivisions of structured administrative levels (from local to global) of the continents and of distinct historical periods? What would we see on the three invisible faces of the cube if we rotated the object in a computer simulation? Which classes would they correspond to and which would be missing? What would happen if we replaced one of these categories with the other? Such questions would not come to mind in current representations of interfaces that seamlessly connect data at first sight into a unified, but ultimately problematic, homogenous whole.

Otlet's struggle to find ways of combining the representations of three-dimensional knowledge objects was not limited to *Monde* but characterizes a range of his attempts to create effective representations of the sciences and society. In the visualizations of knowledge objects, however, Otlet is not bypassing problems of data integration and scalability but in a creative way is facing tensions of representation, incompatibility, and inoperability related to them. Such an approach carried out today might well help to clarify problems related to more effective data integration than we now have and suggest new solutions for them.

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