An Integrated Reading and Editing Environment for Scholarly Research on Literary Works and their Handwritten Sources

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ABSTRACT

We present an integrated system devoted to the visualization and the editing of hypermedia documents from literary material including document images and structured text. First, capabilities are offered to transcribe manuscript images. Transcribing the text consists in coupling lines typed on the keyboard with their corresponding text lines in the manuscript images. A semi-automatic system based on computer-human interaction and document analysis is proposed for performing this task. This system provides editing capabilities for linking document images and the corresponding structured textual representations (encoded by means of a logical markup language). Finally, application-specific visualization tools have been developed in order to provide users with an idea of the overall organization of the hyperdocument and help them to navigate.

KEYWORDS: hypermedia, reading/editing environment, text / image coupling, image analysis, text encoding, information visualization

INTRODUCTION

As digitizing and multimedia technologies are developing, digital libraries are likely to hold and make available vast collections of documents representative of the literary heritage.

While setting up and organizing digital repositories to provide better access to vast amounts of heterogeneous data is a major topic in digital library research, it seems that less work has been devoted to the development of an integrated environment for scholarly qualitative research on this material. The Computer-Aided Reading Environment ("Poste de Lecture Assistee par Ordinateur" or PLAO) developed within the context of the new French National Library project in Paris between 1990 and 1993 may be recalled as one of the few projects that dealt explicitly with this issue [17]. The PLAO project was expected to provide professional users with innovative tools to work on documents from the library collections. However this project was not brought to full completion.

Although it can be seen in some way as a continuation of the PLAO, the system presented here differs from it in several aspects. On the one hand, our system takes into account advances in networking, document analysis and visualization techniques, while the PLAO was mainly an isolated workstation with classical human-computer interaction features. On the other hand, while designing this system we tried to address problems related to the complex nature of literary works from a more theoretical point of view.

In fact, literary works can often be seen either as texts or graphical objects. For example, depending on his current research interests, a scholar may be mainly concerned with the textual or the ornamental features of a given manuscript. Within the context of a Digital Library, available textual representations may range from raw transcriptions to sophisticated SGML-encoded scholarly editions. While being easy to read and lending themselves to easy computerized manipulation, these text-based representations are not very good at recording the graphical features of ancient documents. On the other hand, visual representations like digital images of manuscripts or ancient books can to some extent be relied on to convey graphical information but are difficult to process automatically.

Thus, when building a computerized research environment dedicated to the study of literary documents, one of the most important design goals is to ensure that the system will provide suitable linking tools to integrate both the textual and image representations of the works being studied.

In addition to the above mentioned duality, the complex nature of literary works also lies in the fact that for a literature specialist or a philologist, a given work can not be reduced to a single canonical text but consists of a large set of heterogeneous data (handwritten copies of ancient works, authorial manuscripts of modern works, transcriptions, scholarly editions, commentaries, etc.). Efficient navigation and visu-

alization tools are clearly needed for browsing all this data. Given the complexity of the material to be dealt with the design of such tools is likely to provide useful insights for managing larger collections.

We first describe the underlying principles of the system. We then present an integrated system for the production of typed transcriptions from complex manuscripts which is based on computer-human interaction and document analysis. The following sections detail the tools provided for linking document images and structured text at several granularity levels and for visualizing the large heterogeneous set of data that constitutes the literary hypermedia document. We conclude with related work and future plans.

UNDERLYING PRINCIPLES

Handwritten sources of literary works are complex objects which are often hard to decipher. This is because of the dual nature of manuscripts that can either be seen as bitmap images "containing" text and graphic elements or as pure textual representations. In other words, manuscripts can be seen as texts with a graphical interest [1].

Textual images often contain several blocks of text that are not arranged in a linear way (figure 1). For instance, a couple of lines located in the body the text may refer to a note, a reference or a newer version located in the margin. Various blocks of text can possibly be linked together with arrows or other graphical markings thus making reference to each other. Certain words, sentences, paragraphs may have been crossed out, and this at successive steps of the writing process. Finally, authors often produced several preliminary versions of the same page. This temporal dimension is the reason why for some specialists of manuscripts, "writing is a storage medium, a track, and also the process producing this track"[8].

So, in order to work on a manuscript, one has to transcribe and interpret it in some way. We describe below the underlying principles of the tools offered by the system to help the user perform both tasks.

The classical transcription task consists in editing a typed version of the manuscripts from their original images, while respecting their graphic aspect (the spatial disposition of text lines must be preserved as well as erasures and other editing marks). The transcription corresponds to an intermediate state between image and text: it is text with topological attributes. The whole document can then be organized by means of a direct manipulation metaphor, in order to create links between its various components or with external data, or to generate index tables. Hence, manuscripts can then be seen as *"hyperscripts"*.

Graphical User Interfaces and Hypermedia capabilities can considerably ease and enrich this transcription task. First, hypermedia facilities make it possible to attach relevant information such as notes, comments and other related documents (containing text, images or sound) to the text that is being studied. But this kind of techniques can also provide efficient means for performing a close coupling between the pure textual data and the image that contains the original

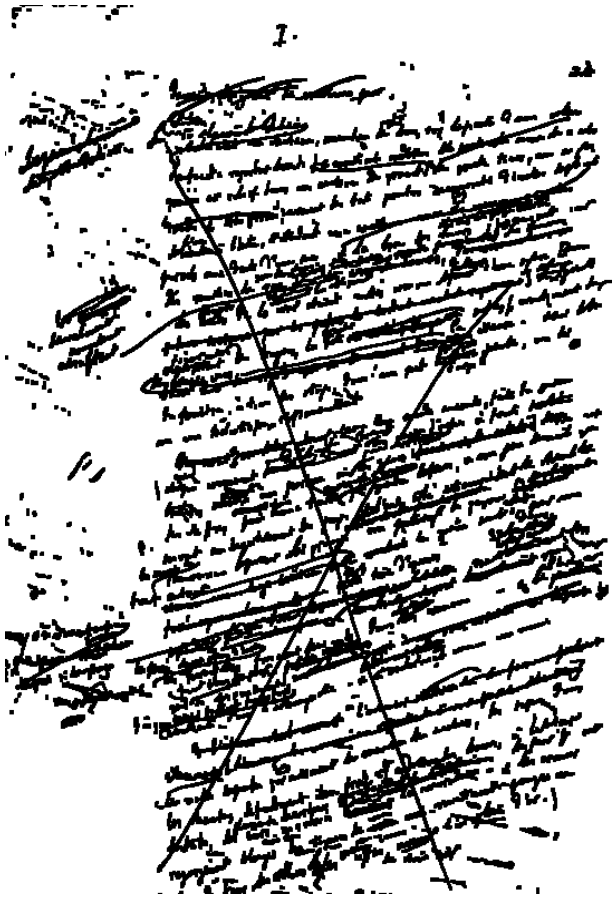

Figure 1: A page from a Flaubert's manuscript.

representation of this text. This problem has not often been addressed, most studies having being held either on textual or graphical aspects.

Many technical solutions are available for representing various kinds of textual data. Among the most successful encoding schemes are logical markup languages which make it possible to define common languages for a community of researchers and thus, facilitate common work on this data. Furthermore, the use of this kind of encoding scheme can also greatly improve automatic processing when using search engines and other programs for building index tables, computing statistics, etc. But logical markup languages provide limited ways for representing the graphical characteristics of the original text. They have been primarily designed for representing printed text, that is to say text that follows a well known structure (for instance the book/chapter/section structure) that is basically mono-dimensional (top/down and left/right).

Encoding spatial relationships between textual and graphical objects could quickly become quite a challenging task and result in very complex specifications that would be hard to use. This is because textual images are not "mono-dimensional" in nature: one must consider 2D layout, "links" between various parts of text (possibly located on different pages), successive modifications, etc. In some way, they present similar charac-

teristics to modern Web pages that contain iconic and textual objects (these being often rendered by using various fonts and colors) arranged in a 2D layout and making reference to each other, either by spatial proximity or through hyperlinks.

Consequently, besides classical hypermedia capabilities, the presented system proposes the principle of structured text / image coupling to integrate complementary representations of the same original medium that are usually processed separately [1]. In other words, this could be seen as an attempt to "map" an external visual representation (the text image) to an internal representation (the text encoding) that can be easily processed by using classical software while retaining all the visual information. This integration is needed in order to be able to interpret literary sources in a comprehensive way.

As dealing with large documents in a fully interactive way could become a tedious task, we propose a *semi-automatic* approach that lets the user validate or correct interactively transcription hypotheses that are automatically provided by the document analysis module described below. Document analysis is mostly required for transcription purposes as the transcribed text reflects the layout of the manuscript. Automatic processing includes the separation of the handwritten text from graphical elements and the segmentation of the text into text lines.

The tools and approaches used to help the user perform the above mentioned tasks are described in the following sections.

EDITING CAPABILITIES AND TEXT / IMAGE COUPLING

Links and Interactive Tools

The presented system lets the user create links in an homogeneous way. In this model, the document components are connected interactively by adding graphic tracks (i.e. sensitive areas) in the manuscript images and/or in the transcribed text (figure 2). These graphic tracks can be "dropped" in a direct manipulation style by using tools called *interactive markers* that will be described in the next sub-section. These tracks can then be associated to another part of the document, or to external data.

Several types of links have been defined. First, *transcription links* associate image elements in the manuscripts with their corresponding textual elements in the textual transcriptions (figure 2e). This type of links and the corresponding edition process are detailed in the next section. *Internal links* make it possible to associate various areas in the manuscript images or in the transcriptions. It is thus possible to create meaningful associations between words (or lines) contained in the manuscript images, in the transcriptions or in the note sections. *External links* provide a way to anchor heterogeneous hypermedia entities (text, image, sound, video) contained in other documents. Finally it is also possible to define *index tables*. Indexes are used to access the content of the document from selected keywords in order to navigate efficiently through the electronic book. These items are also associated to graphic tracks that are defined in the manuscript images and in the transcriptions.

During the transcription phase, selection generates automatic

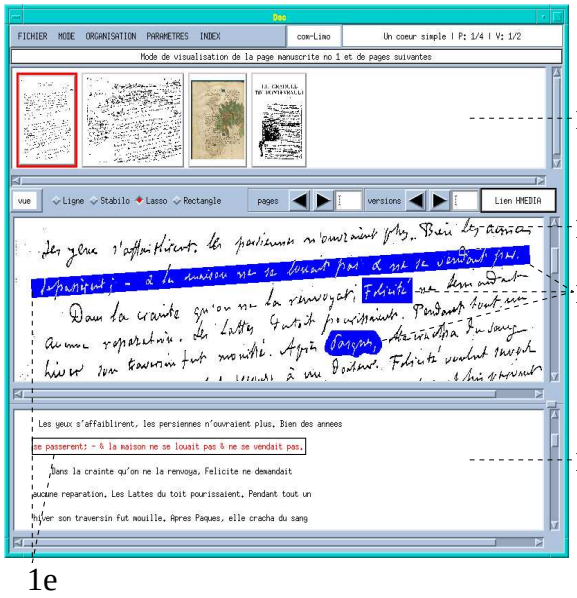

Figure 2: **The main window of the application. a): The visualization area where manuscript images and transcriptions can be displayed as small scale images. b): The current manuscript image (facsimile). c): Sensitive areas defined into the document by using the markers. d): The transcription. e): A transcription link.**

link creation between the selected handwritten text and the corresponding typed text. The user can take advantage of these links during the visualization of the document and its transcription as clicking on a manuscript image area automatically highlights the corresponding typed text in the transcription (and vice versa).

Creating the Transcription

The transcribed text is created in two successive steps. The user first selects the handwritten text in the manuscript image and can then type the corresponding ASCII text. The system provides automatic layout capabilities: once entered, the typed text is automatically located in a way that respects the spatial disposition in the original manuscript image. We have also developed protocols based on image analysis and computer-human interaction techniques for selecting areas of a document image. As mentioned before, the interactive selection process can also be helped by an automatic page analysis stage that determines line segmentation hypothesis.

Four kinds of interactive markers are provided for the user (figure 3). These tools make it possible to drop a graphic track on or around the handwritten text that has to be selected. The first two markers are based on the *stabilo model*. They make it possible to highlight a text line or a subpart of it (for instance for highlighting a single word or a group of words). The first marker (or line marker) is used to select a straight line (i.e. a thin rectangle area) on the text image while the second marker (or stabilo marker) can be used to follow fluctuating text lines. This marker is materialized by a roll that follows the user's freehand line.

The two other markers have been designed for framing several

[1] Preliminary achievements of this system were presented in [14].

Figure 3: Transcription tools and interactive markers.

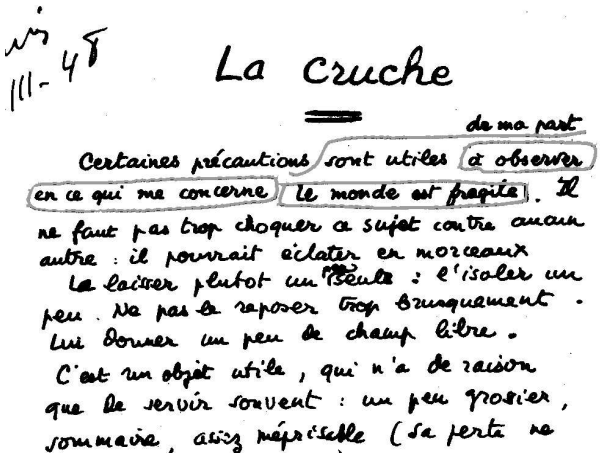

Figure 4: **Manuscript of the French writer Ponge. Surrounding and insertion lines extracted by the Kalman filter appear in grey color.**

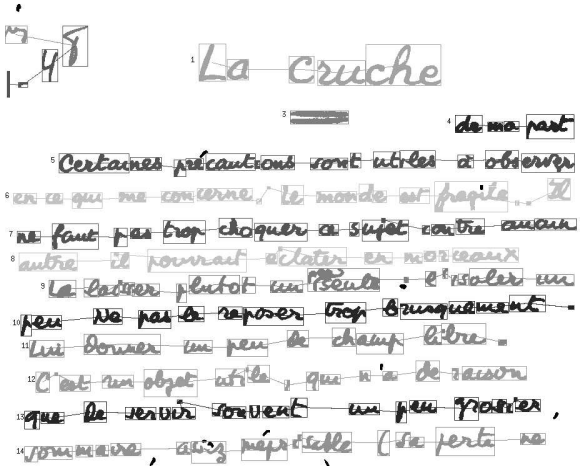

Figure 5: **Text Line segmentation on the image after having removed graphical elements.**

lines of text or any arbitrary part of the manuscript image. The rectangle marker is used to define large image areas or to select a part which is well separated from the main text. Finally, the lasso marker enables the user to define areas with various shapes. He can thus accurately follow the boundary of the area he has to select, when necessary.

Document Analysis

Document analysis consists in extracting the structure and the content from document images. An ideal document processing tool dedicated to handwritten pages would perform the separation of the handwritten text from graphical elements, the segmentation of the text into text lines and words, the recognition of the handwritten characters or words.

But the great variety in handwritten shapes and layouts involves that these requirements may only be applied on manuscripts containing enough spacing between columns, well separated and calligraphed characters and few non textual graphical elements.

Interactive or semi-interactive tools are offered for dealing with other kinds of manuscripts. We aim here at combining document analysis with computer-human interaction for the extraction of graphical elements and text lines in unconstrained manuscripts.

Extraction of Graphical Elements Graphical elements are non textual items, which may be superimposed on the writing: big crosses toward the page, arrows, erasures are encountered. The significance of these signs is of great interest for the literary study of such texts, especially genetic criticism.

Graphical elements superimposed on the textual part impede document structure analysis and the deciphering of the manuscript on the screen. We are concerned here with the extraction of filiform elements like crosses, lines referencing different parts of the page, lines surrounding pieces of text. These graphical elements may be interrupted and their aspect may be close to written ones.

Kalman filtering is a popular image processing technique used to follow objects in images. It was successfully applied to follow lines in musical scores [13]. We use it here to follow graphical elements after they have been pointed with the mouse on the screen [9]. The element to follow is an object represented by a vector whose parameters are : the position in the image of the center of the line, its width, and the slope of its trajectory. The object is extracted when its position and width are computed from its initial position to its end.

The ideal trajectory is modeled as a straight line of constant width. This trajectory is confronted to image data observed in the image. The principle of Kalman filtering is to estimate the element step by step along its trajectory by considering the difference between the ideal object, the observed object and the expected errors.

Figure 4 shows the extraction of four graphical elements on a manuscript of the French writer Ponge : three surrounding lines and one insertion line. Each one was first pointed at the beginning of the stroke to initialize the Kalman filter. If the filter stops before it reaches the end of the element, the user can make the filter continue by clicking again at the last

position reached.

Text Line Segmentation As the transcription task involves coupling text lines of the manuscript with typed text, line selection may be eased with automatic line segmentation on the image document. Text line segmentation should occur after having separated the text from the graphical elements. Handwritten documents, especially author manuscripts, may present fluctuating or interwoven lines, irregular spacing between lines and words, insertions between lines and include several text line directions. Methods developed for printed material can hardly be applied to handwritten documents. We have developed a segmentation method devoted to unconstrained documents [10]. However, when dealing with Flaubert's manuscripts which may present very complex layouts (figure 1), we may take advantage of automatic segmentation for documents which are close to the final version of the manuscript.

The proposed method is an ascending process grouping connected components into text lines. Grouping is done under perceptive criteria which are proximity, similarity and direction continuity. The iterative strategy is recalled below.

First, connected components which have a reliable direction are selected as directional anchor points. Each anchor point constitutes the starting point of an alignment. Alignments are formed by linking neighboring components to anchor points by perceptive criteria. Then the quality of each alignment is evaluated. Alignment conflicts are solved by applying a set of rules which consider alignments' configuration and their quality. After a few iterations, the complete alignments appear. At each iteration, the proximity constraint is relaxed in order to link more distant components.

At present, processing time is too long to be called on request when transcribing. It takes a few minutes on a whole page to perform component labeling, anchor point selection and grouping. Images are then pre-processed off-line, thus sparing the user the trouble of waiting. For each line, the coordinates of its components are provided.

The resulting data are available to the user who may validate or not the alignments found. Refinements will consist in interactively adding or deleting some components from alignments if necessary. For instance, on figure 5, text line segmentation was performed on the image shown on figure 4 after having removed most graphical elements. The alignments found appear in different grey levels and components which constitute the alignments are linked in the right order. However, the component enclosing digit "8" (in the upper left of the manuscript) should be removed from the above alignment by interactive correction.

DOCUMENT IMAGES AND LOGICALLY STRUCTURED EDITIONS

Besides manuscripts, digital libraries are likely to hold and make available structured editions that may prove to be useful for studying literary works. Examples include the many critical editions produced by scholars in the course of time.

Critical editions are scholarly editions which take into account the fact that literary works, especially ancient texts,

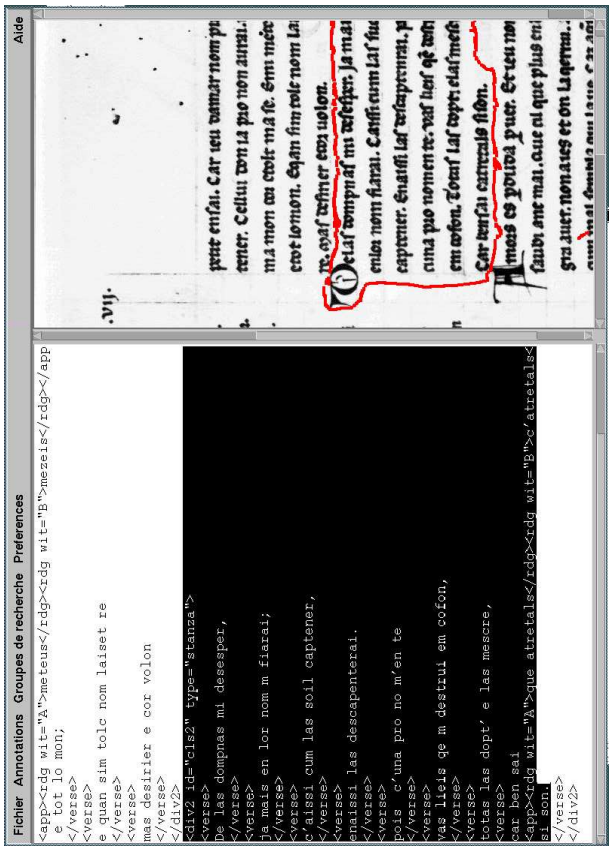

Figure 6: **An image area (right panel) being associated with the <stanza> SGML element (left panel).**

have been hand copied or printed many times over the years and thus may contain many of textual variations. Critical editions are created from collation of available witnesses to a text (manuscripts, ancient printed books, etc.) In these editions textual variants are identified and organized into a critical apparatus. For example the TEI Guidelines [16] provide specific SGML element and attribute sets for creating such critical editions.

Critical editions are encoded in a highly structured form in contrast to the flat nature of manuscript images or linear transcriptions. Given this structural aspect they lend themselves to easy manipulation by computerized systems. For example, when working on a logically encoded edition one can restrict a search to the contents of a particular type of element; it is possible to move quickly around in the document using a view of the tree structure, etc. At the same time structured documents are by nature not very good at representing the visual features of a document that may be of interest to a manuscripts specialist like paleographic, ornamental or layout characteristics. As shown in [15], even very rich DTDs like the TEI DTD, which include some element types for describing presentational and paleographic features inevitably fail to record the visual appearance of source manuscripts. Consequently, it seems that scholars must rely on facsimiles if they don't want to lose information ; but at the same time they will wish to perform the same operations on these exact copies as if they were logically marked up documents.

A possible way to solve this dilemma is to design a system where both the visual and logically (SGML) encoded representations can be processed in parallel. Consider for example a medieval work by the French troubador Bernard de Ventadour. We have at our disposal two hand-written versions of this work in bitmap image format and a SGML encoded critical edition created from these manuscripts. As already said, the edition is not an exact copy of the original manuscripts. On the one hand the scholar who authored it was mainly interested in linguistic data and therefore did not try to record information about the layout or appearance of the hand written copies. On the contrary, he inserted punctuation marks, replaced some words with modern orthographic forms, did not record the original line breaks (scriptio continua) but put each verse on a separate line. This is normal practice to help other users to read and exploit textual material which is otherwise hard to decipher or interpret. Seen in this light, the changes made to the source manuscripts can be seen as value-added information which in our approach should be combined with the visual richness of the originals. In the following paragraphs we give an overview of the prototype we are currently building to reach this goal.

Suppose an user wants to work on Ventadour's work. He or she can load into his personal workspace both the manuscript image and the SGML transcription. Using the mouse he or she can define some image areas (for example areas containing stanza or verses) and link them to the equivalent logical elements in the SGML document. Figure 6 shows an image area being associated with a <stanza> element). Once these links have been created the user is provided with new investigation possibilities. He can, among other things, move around in the image from one logical zone to the other. Besides that, if he only loaded the manuscript image when clicking in an area, he can at any time access the equivalent logical element which can be displayed on request in a separate window.

Let us finally consider some examples involving SGML attributes. A SGML element often carries attributes which help precise the meaning of this element. For example, the TEI Guidelines provide paleographic attributes to qualify a piece of written text as regards its paleographic features (to indicate which abbreviations are in use, which hand wrote this particular piece of text, etc.). When clicking on a given image area previously linked to the SGML transcription, one can request the attributes of the corresponding logical element to be displayed. The TEI Guidelines also provide a 'sigil' attribute to indicate in which manuscript a given textual variant has been found. Using this information as a bridge, one can jump directly from an image area containing a given textual variant to all relevant image areas in another manuscripts.

BROWSING AND NAVIGATION

From a specialist point of view, a literary work does not come as a single isolated document but consist of a large set of heterogeneous data (manuscripts, ancient editions, commentaries, etc.). For example, as far as ancient works are concerned, the relationships between the many handwritten copies produced by different copyists since the Middle Ages should be represented. Similarly, as far as modern works are concerned, there may be cases when the specialist wishes to relate the many layers of writing that may be found on the same page. An efficient hypermedia system is required to browse and visualize all this data.

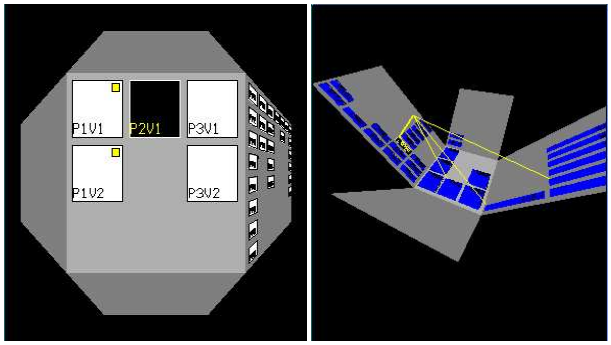

Figure 7: **Left: the front side of the wall represents manuscript images (horizontally the pages and vertically the different chronological versions). Right: the links between the selected page and the related components are displayed on the backside of the wall.**

Visualizing and exploring large information spaces are difficult tasks [6]. In an hypermedia system the representation of the document is critical to allow users to navigate more efficiently. It is quite important to provide the user with global knowledge of the document organization in order to facilitate navigation through the different parts of the hypermedia. Consequently, we have developed tools for both visualizing the organization of the hypermedia and the context of a detailed document.

First, a specialized browser has been designed to display the manuscript images and the corresponding transcriptions (figure 2). This tool can either be used for editing new transcriptions from manuscripts or for browsing pre-existing material. Components of the hypermedia document can be displayed in different ways. For instance, several documents can be visualized simultaneously as small scale images in order to provide users with an idea of the nature and the shape of the current manuscript (the one that the user is currently looking at) and of the other manuscripts which are related to it and correspond to its context.

The document structure is visualized by means of a 3D representation that is based on the Perspective Wall paradigm [11] [5]. This model has been adapted to our research domain in the following ways. First, it must be noted that the structure of the documents we have to deal with is generally of a bi-dimensional nature. In the case of ancient works, several *variants* of manuscript pages are generally available. In the case of modern works, the author often produced several successive *versions* of most pages. The visualization model follows this structure in a rather straightforward way (fig. 7): pages are represented horizontally on the wall, while variants or versions are represented vertically (i.e. a column will contain all the possible variants or versions of a given page).

Pages are represented on the wall by means of icons which are linked to the "focus view" provided by the manuscript / transcription browser. Both views are thus synchronized: se-

lecting a given icon of the wall will display the corresponding pages in the browser and vise-versa.

The original model was also extended in order to represent links between pages. Links that are related to a given page are displayed on the back side of the wall when this page is selected. This representation makes it possible to show relationships between pages in a rather simple and convenient way.

So, this dual representation makes it possible to represent simultaneously focus and context. The selected manuscript (the current focal point) is browsed at normal size in a window of the main application while its context and the global organization are represented by the 3D visualization system.

COMPARISON WITH RELATED WORK

General paradigms and models have been proposed for dealing with compound modern documents (e.g. OpenDoc, OLE, the multivalent document model developed within the Berkeley Digital Library project, etc.). As far as ancient documents are concerned, there are also electronic publishing projects devoted to the edition of ancient works and their sources (e.g. the famous Canterbury Tales Project [3]) or isolated tools for annotating images for scholarly purposes developed by some institutes for advanced technologies in the humanities.

We focus here on the few systems allowing scholars to handle works with multiple layers of related content within the context of a real-world digital library providing in an integrated way both a set of related documents and highly specialized tools for working with these documents.

The PLAO system we already mentioned in the introduction of this paper certainly falls into this category [17]. It was intended to enable professional users of the future French National Library in Paris. One of the original aspects of the project was that it started after a detailed analysis of the complex reading and research habits of the professional users (teachers, scholars, students, etc) who were likely to access the digital collections of the future library.

As in our system the design approach was to maintain a symmetry between the handling of text and image formats. In keeping with this principle, page images and textual documents could be annotated using the same kind of markers. However the PLAO was intended for the handling of digital versions of printed books, not manuscripts. Thus the system included a general purpose OCR module only suitable for modern printed editions. The system also lacked advanced visualization devices.

The BAMBI project (Better Access to Manuscripts and their Images) [2] was funded by the European Community until 1997 as part of the "Telematics for Libraries" Programme. The objective of the project was to develop a so called "Philological Workstation". It aimed at providing philologists, papyrologists and other scholars with tools for facilitating the transcription of medieval texts. However, the system was restricted to the handling of ancient manuscripts. In particular, it did not address specific document analysis problems that are often encountered when dealing with complex modern authorial manuscripts. Furthermore, BAMBI did not include advanced visualization tools for displaying a literary work in the context of other related documents held at the digital library.

CONTRIBUTION TO THE FIELD AND FUTURE WORK

We have presented a system devoted to the handling of complex literary works with rich handwritten and printed sources. This system unites several layers of information in order to provide the user with global knowledge of the work. Several specialized tools have been designed for this purpose.

What distinguishes our system from other environments is that it tries to integrate techniques usually developed in separate research communities (image analysis, structured documents and visualization techniques). Moreover, it should be noticed that this system was designed in a participatory way in cooperation with experts from French institutes (ITEM / CNRS, IRHT) working on the study of literary handwritten sources [4].

Future work will first consist in enlarging the class of documents that can be processed automatically by the image analysis module. We will also focus on the representation of hypermedia documents and on the development and the testing of new techniques for information visualization. Concerning networking issues, we plan to adopt a modular architecture in which net related functions are clearly separated from multimedia display functions as suggested in [7]. Also, we plan to integrate a Z39.50 search tool for accessing both documents and related metadata.

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