SECTION I: INFORMATION DESIGN AND SYSTEM DEVELOPMENT

Team-based Coordinated Development of Hypermedia: Lessons Learned from Piero della Francesca's "Agostinian Polyptych"

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Abstract

Developing a complex hypermedia application is a team-based process, involving a variety of "actors"—analysts, domain experts, graphic designers, implementors. The quality and cost-effectiveness of the final product is largely dependent on the ability of planning the overall development phases and of coordinating the effort of team members in an efficient way. In this paper, we will present our experience in the "Polyptych" project where we built a large hypermedia application for the Poldi Pezzoli Museum in Milano. We will discuss how we structured the activities of the development process, pointing out some novel aspects of our approach.

Keywords

hypermedia authoring, hypermedia design, cooperative work

1. Background

"Polyptych" is a hypermedia application that aims to present a complex set of research in history of art, concerning the so called "Agostinian Polyptych". The Agostinian Polyptych, by the Italian Renaissance painter Piero della Francesca, is one of the most problematic works of this artist: along the centuries, it was disaggregated, its various components were dispersed, and the central panel and some paintings in the basement were never found. The other pieces—discovered in different places and acquired by different museums—are now exhibited in different countries: the Frick Collection in New York, the National Gallery in Lisbon, the National Gallery in Washington, the National Gallery in London, and the Poldi Pezzoli Museum in Milano.

From an art historical perspective, this masterpiece raises a number of scientific problems:

- proving, with a rigorous and scientific approach, that all the existing components actually belong to the "Agostinian Polyptych" and not to other works by Piero della Francesca;
- identifying the structural relationships among them (i.e., which elements were placed where in the Polyptych architecture);
- proposing a reconstruction hypothesis, suggesting potential content and shape of the missing components.

For five years, these problems have been studied by a team of Italian researchers from different institutions coordinated by the Poldi Pezzoli Museum in Milano (Opificio delle Pietre Dure in Florence, Museum of Costumes in Florence University of Lecce, University "La Sapienza" of Rome, University of Geneva) and cooperating with major international museums (National Gallery of London, National Museum of Lisbon, Frick Collection in New York, National Gallery in Washington). The study was based on the analysis of recent and old restorations of the Agostinian Polyptych, the investigation of ancient documents, and the compared analysis of sculpture, textile, costumes, fashion, jewelry, and habits in the Italian Renaissance. To present the results of their work both to the scientific community and to a larger audience, the research team decided to combine three approaches: to publish a paper book, to organize a temporary exhibition showing panels and physical pieces of the Polyptych, and to develop a hypermedia making available all the research material in a multimedia interactive way. In the rest of this paper, we will discuss the experience of this project, named "Polyptych". We will focus on how we have managed the development effort and coordinated the activities of our working team, in order to produce a good product in a cost effective way by the project deadline.

2. THE PROBLEM

The development of "Polyptych" has been problematic not only because of the *specificity* of the content (the topic is very specialist—a single polyptych!), the need to address a *variety of user categories* (from art specialists to Renaissance "lovers" and "average" museum visitors, and the *limited budget* and a short-term deadline for delivering the system, but above all, by the complexity introduced by the *size* and *nature* of the *working team*, involving a variety of "actors": one analyst, on "conceptual" designer, one graphic designer, three implementors, the project manager, the editorial manager, and *eleven* content authors (all the members of the initial research team). An heterogeneous team is typical of any complex hypermedia; in our case, however, it was particular critical since each of our eleven authors is specialized in a different subject, belongs to a different institution in a different area of Italy, and when the project started had *no experience of hypermedia, nor in creating content for electronic use.*

While team-based development of generic software products has been widely studied by the software engineering community, to our knowledge no published work exists that analyzes this process specifically for hypermedia, and no guidelines are available. As a consequence, we had to define our own model of cooperative hypermedia development, which is summarized in the following section and illustrated more precisely in the rest of this paper.

3. SUMMARY OF OUR APPROACH

Before starting any implementation activity, we structured the development process as a number of tasks, precisely defining the various responsibilities of the team members and giving precise deadlines for each task. The following Table 1 outlines the major activities we defined; although they are listed in sequence, they are interrelated and may have cycles and parallel evolutions.

The most innovative aspects of our development process, which helped us to proceed in a cost effective way and to get to a usable product by the project deadline, are the following:

- we made a *significant investment of resources* in the preliminary phases of requirements analysis and conceptual design, trying to anticipate potential problems as much as possible and to come out with a precise set of specifications for the implementors.
- Both requirements analysis and conceptual design in Polyptych were *model driven*, i.e., used a set of conceptual primitives and guidelines to describe the features of the system under various points of view, capturing the essential features and skipping the unnecessary details
- We imposed *strong constraints* on the authors in the process of content production
- We provided authors with a template-based *tool for content production*, defined according to the structural and lay-out constraints identified in the design phase.

The following sections will discuss these aspects more precisely.

3. REQUIREMENT ANALYSIS IN POLYPTYCH

To specify the user requirements of Polyptych in a precise way, we adopted the *W5* model (Who/ Why/ What/Where/When) defined at the Open Hypermedia Research Center—HOC at Politecnico di Milano.

In summary, W5 prescribes the specificaiton of a *grid of attributes*, to identify:

- "who" are the intended users of the application
- "why", i.e., for which task, each category of users presumably would use the system
- "what" is the content for each category of users and tasks, what are the most appropriate media, representation structures, interaction styles and access paradigms to access the content.
- "where" is the system going to be used (i.e., in which physical context: the museum entrance, for example, or the library, or the reading room)
- "when" will it be used, and for how long, in the different situations.

Task	Purpose	Responsible(s)	Involved
requirement analysis	collect and analyze the user requirements, in order to identify the user profiles and goals, the overall "message" of the application, the needed media, the content nature	the analyst	
conceptual design	define the structures to organize the content, their behavior, and the functionalities to access it (e.g., navigation, search...)	the designer	all authors (for feedback)
objects identification	list the actual "content entities" to be presented in the application		
lay-out design	the user interface visual features, such as window background shape, button arrangement and shape, are defined		(or feedback) all authors the analyst the designer
structures, functionalities, and lay-out ***implementation***	implement the navigation, search, and user control functionalities, lay-out objects	the implementors	
content production: • **content creation** • **content recording** • **content adaptation**	3 sub-phases: • create the actual content, or collect if already existing • digitalize and store the content in digital form, in an organized way • revise the content to make it appropriate for electronic "reading"	• all authors • the implementors • the editorial manager	
application population	the actual content is inserted in the application skeleton	the implementor	
technical and usability testing	test the technical robustness and efficiency, and inspect usability properties	the designer	all authors external "inspectors"

Table 1: The development process model of Polyptych

Requirements analysis was carried on by the project analyst, by interviewing the content experts both in the authoring team and from other museums. Users have been classified in three major user categories [6,8], each of them precisely characterized in W5 terms (briefly summarized in Table 2).

4. CONCEPTUAL DESIGN IN POLYPTYCH

Based on the output of the requirements analysis phase, during conceptual design we specified the information structures of the application, the navigation facilities and dynamic behavior of the multimedia objects. For this activity, we adopted the design primitives of HDM (Hypermedia Design Model), defined by our research group at Politecnico di Milano. The following is a short summary of HDM main concepts; the reader is referred to the proper references for further details [1,2,3,4,5,7]

HDM distinguishes between the *hyperbase layer* and the *access layer* of an application. The hyperbase layer is the backbone of the application and contains the building blocks of the application content, while the access layer provides entry points to the hyperbase. The hyperbase consists of *entities* and

Who	Why	What	Where	When
"casual" visitors just passing through the information point by chance. For them the application is a "walk-up-and-use" system that is only intended to be used once, probably for a short time. They might differ in their skill about computers and hypermedia technology	to get an immediate feeling of what the research is about; curiosity	simple but attractive, information about the research aim and topics ***media:*** audio + images + animation; ***structure:*** linear (set of sequential guided tours) ***interaction paradigm:*** mostly automatic (slide-show) navigation; few simple navigation commands	museum entrance, exhibition rooms	during museum or exhibition visit duration of a session of use: 5-15 minutes
"intentional" visitors They have some knowledge, or, at least, a significant interest, about the subject domain and want to learn more about it. They might differ in their knowledge about hypermedia technology and in the amount of time available to explore the application	learning more about Art Renaissance and specific subject of the application teaching at high-school level	"robust", but non strictly specialist information about the research topics ***media:*** text + audio + images + animation ***structure:*** trees ***interaction paradigm:*** free navigation	museum entrance; exhibition rooms teaching room at high school	during museum or exhibition visit; during high school lectures; duration of a session of use: 15-50 minutes
"specialists" in the application domain, e.g., researchers in history of art Again, they might differ in knowledge about technology and in the time available to use the application	research purposes; teaching at University level;	complex specialist information about the research results ***media:*** text + audio + images ***structure:*** trees ***interaction paradigm:*** free navigation	museum reading room; research laboratory or office; teaching room at University	during research work; during University lectures; during museum or exhibition visit; duration of a session of use: 30 minutes - several hours

*Table 2: **W5 specification of Polyptych user requirements***

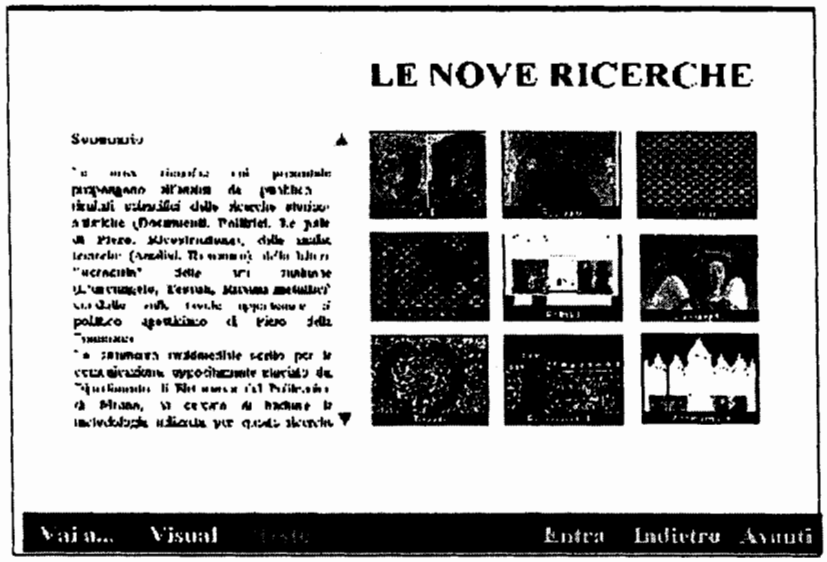

Figure 1: Index page of Polyptych

connections, called webs, among (parts of) them. Entities are composite structures; their constituents are called *components*, which in turn are made of *nodes*. Nodes are the navigational units of the application—they may correspond to "pages", page sections, or full screen windows. A node consists of a number of *slots*, each one representing an atomic unit of interaction. A slot can be complex, i.e. it may include a number of different synchronized media, but is still an atomic unit from an application point of view. The access layer consists of a number of *collections*. A collection groups a number of "members", in order to make them accessible. Members of a collections could be either hyperbase elements or other collections (nested collections). Examples of collections are guided tours [9], tables of contents, indexes or sub-indexes, etc. For the various structures, HDM describes the navigational behavior, i.e., the way of navigating inside and cross the various elements, by means of *structural* and *applicative links*. The various structures and dynamic properties can be described from at different granularity's: in-the-large (where the general properties are taken into account) and in-the-small (where the details are provided).

In Polyptych, the access layer contains **eight main collections** that we called "**Paths**" : "Reconstruction", "Technical Analysis", "Restoration", "Fashion", "Textiles", "Jewelry", "Archive Documents", "Renaissance Art Related Works". Each path corresponds to a sub-study of the global study, and its content was been created by a different group of art historians.

The Index page that allows to access the various paths in Polyptych is shown in figure 1.

All collections have a similar organization, consisting of a short Introduction, and a set of "sections". The introduction contains two nodes: one node stores an image and a text comment about the path, and the other node contains a picture showing the path structure (to allow the user select a section and access it directly). A section is modeled as an entity, and corresponds to a topic of the sub-study represented by a path. It is a linear structure of components; the first—called "Summary" contains one node of type *"Visual"* and one node of type *"Text"* the others - called *"Details"*—contain a node of type *"Text"*. A *"Visual"* node consists of a large image, a caption, and an audio comment. A *"Text"* node includes one image or animation, and two or three columns of text. Nodes of type *"Visual"* provide essential, non-specialist information about the sec-

tor revision. The above reported schemes were refined several times before reaching final agreement. *What is important to notice is the advantage of having a design model with a relatively simple set of primitives: it gave a common language to people with totally different technical backgrounds–designers and authors–and allowed us to discuss the various design choices and to anticipate potential problems before writing a single line of implementation code.*

ing titles to each of them and to their components (in the HDM terminology—see appendix). Each author was responsible for object identification for one Path. For each entity of the Path, the author responsible was also required to list (and to start collecting in paper form), the needed images and to draft examples of texts for one or two entities, in order to exemplify the actual content.

Based on the results of this activity, we completed the analysis of implementation and lay-out require-

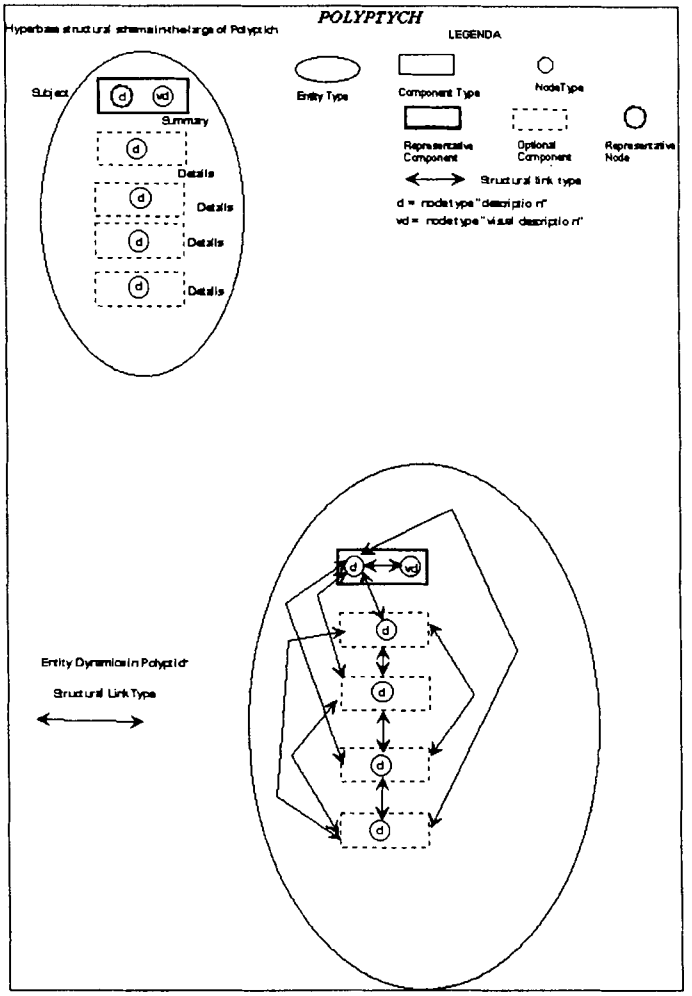

Figure 3: Hyperbase of Polyptych: structural and dynamic schema in-the-large

ments of the application, and proceeded to lay-out the design.

We organized lay-out design in two sub-phases. We first defined a set of *conceptual lay-out templates*; each of them defines the types of data element contained in it (e.g., text, image, animation) and describes a possible arrangement of these elements on the screen; it also lists the needed links and control buttons. Examples of conceptual design templates are shown in figure 6 (with the details of the navigation bar listing all the navigation links that must appear in the node).

In the next sub-phase, conceptual lay-out templates were given to the graphic designer as a sort of *requirements specification* of what the concrete (real) pages of the application must contain. The role of the graphic designer was to transform conceptual templates into *concrete templates*. For each conceptual template, he created a "page" template in the hypermedia *delivery* environment, which contains the concrete visual objects corresponding to the various elements listed in the conceptual template (content fields, navigation and control buttons). He also specified the appropriate type font and size for the various text elements (titles, subtitles, and body),

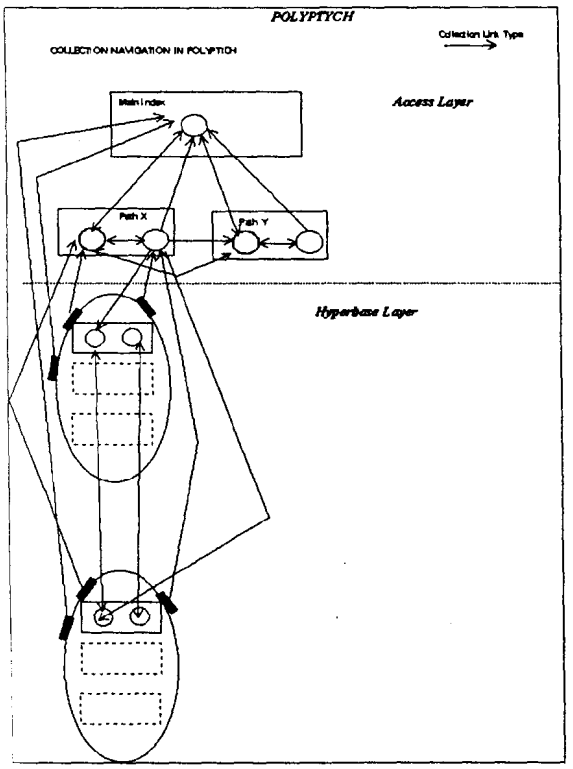

Figure 4: Access layer of Polyptych: dynamic schema in-the-large

the background pattern, the shape, color, icons for the buttons, and all other "decorative" features.

Figure 7 shows an instance of the concrete template corresponding to conceptual lay-out template 1 in figure 6.

6. CONTENT PRODUCTION IN POLYPTYCH

We organized content production in three (interwoven) sub-phases: *content creation*, *content recording*, and *content adaptation*. Content creation is the activity of producing the actual content to be inserted in the templates. Content recording stores the various information fragments in an organized way. Content adaptation has to do with the writing style, and consists of revising the content to adapt it to the user requirements of the application. In the rest of this section, we will focus on the production of textual content, omitting, for lack of space, the discussion related to audio and animation production.

Based on the output of lay-out design, we identified precisely, in terms of number of characters and average number of words, the maximum size of each text element of a concrete page corresponding to a different template, and we gave these requirements to authors to proceed with content production. Unfortunately, we soon realized that they did not follow our instructions; after 2 months of work, they gave us a mess of files largely inconsistent with the lay-out constraints of the templates. The contents were too long (or too short), and needed an intensive re-writing. We therefore decided to invest some effort to build a simple (but powerful) *software tool* to guide and support the authors' work of content creation.

The tool allows authors to create a path, progressively inserting the various entities. For each entity, the author must describe the summary node and the detail nodes if any (see structural schema in fig...). For each node, author must: i) select which template is more appropriate for it (by invoking the template index, which shows miniaturized images of all the conceptual templates defined for the application); ii) provide title, subtitle, and body content;

discussed with them to get feedback and proposals authors to list all the entities of the hyperbase, giv-

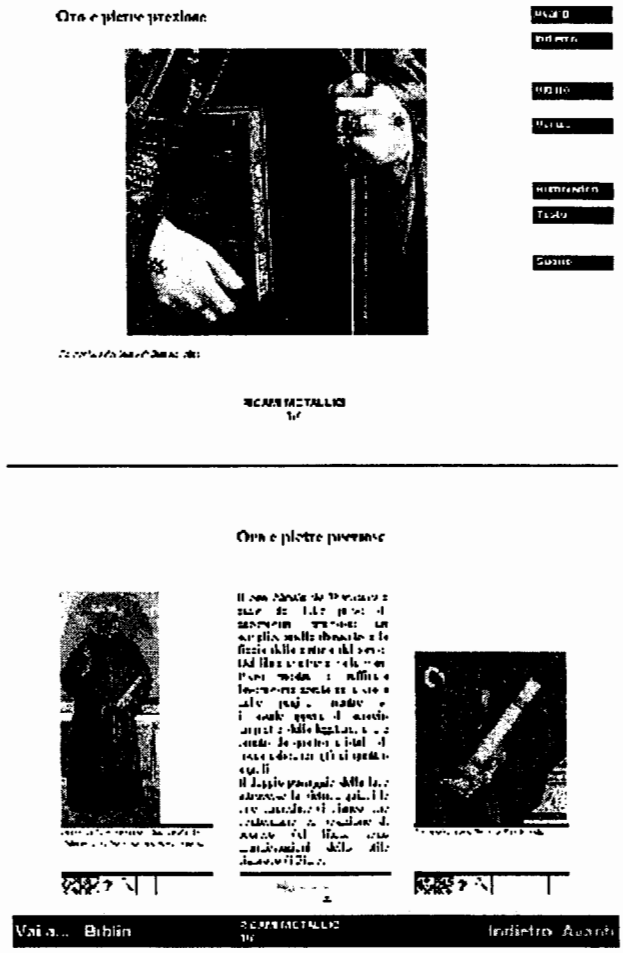

Figure 5: Examples of two nodes (pages) of type "Text" and "Visual"

the body can be either written directly with the tool, imported or cut-pasted from a pre-existing file; and iii) list (according to a given identification format) the figure or figures that are associated to the node. The tool guides authors in this production, warning them when their actions are inconsistent with the structure of the chosen template or when the amount of text exceeds the formatting constraints. As the content creation proceeded, the editorial manager revised it, trying to give an uniform literary style.

The tool also takes care of the content storage: it is responsible for splitting the different segments of text according to their role (title, caption, body, etc.), and storing them in a database management system (DBMS). The database also stores the navigation links connecting the various nodes, *automatically generated* by the authoring tools on the basis of the path structure defined in the application schema. The role of the DBMS is twofold. Firsts, it is necessary to keep a large amount of content well organized, and easy to retrieve and update. Second, it is used by the implementation tools, as explained in the next section.

7. IMPLEMENTATION AND APPLICATION POPULATION TECHNIQUES IN POLYPTYCH

Our implementation technique is based on a sophisticate software architecture which we developed in a previous European project (HIFI) [1] and we specialized for the purposes of Polyptych. The core ideas of this architecture are the following: i) keep-

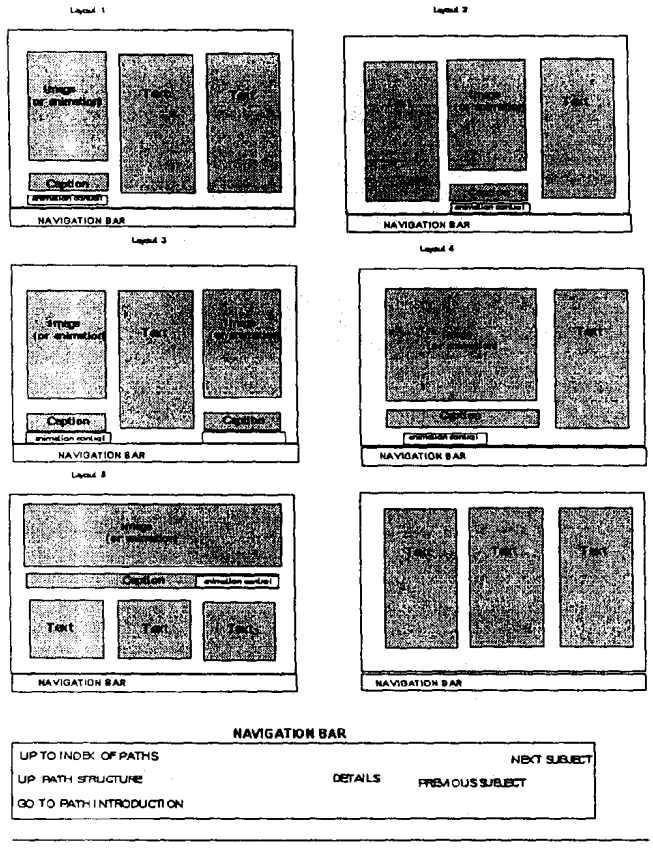

Figure 6: conceptual lay-out templates

ing contents and links in a data base integrated with (but distinct from) the hypermedia application; ii) distinguishing between content "building blocks", presentation (i.e., lay-out) structures and navigation structures; and iii) building the interlinked "pages" of the hypermedia application by means of a *navigation engine* and a *presentation engine*. The navigational engine is responsible for the interpretation of navigation commands: it aggregates the contents stored in a global data base ("union" of the data bases of each individual author), and creates data structures corresponding to the various nodes and links of each (entity of each) path, abstracting from their visual properties. These data structures are then provided, according to an appropriate *protocol,* to the presentation engine, which maps them into concrete pages by creating instances of an appropriate lay-out template and filling in the various lay-out visual elements. The reader is referred to a previously published paper [1] for technical details.

It is important to note that this approach allowed us to proceed in parallel with the activities of content production and implementation, and to populate the application *incrementally*, without being penalized by the many delays of our authors: as authors produced their content, we integrated their databases with the application database, and ran the navigation and presentation engines to generate the corresponding pages in the hypermedia delivery environment.

8. CONCLUSIONS

This paper has reported the experience of developing a large hypermedia system in the domain of art history. One of the major problems we found in this project has been the need to coordinate the activity of a large working team, involving a significant number of authors that are experts in art but were totally naïf regarding hypermedia.

Figure 7: Example of concrete page of Polyptych corresponding to conceptual lay-out template 1

The following are the most innovative aspects of this experience, which allowed us to manage the complexity of the project and to make the overall work more effective:

- structuring the development process in a precise set of tasks
- investing significant effort in the requirements analysis and conceptual design, in order to be able to discuss and anticipate potential problems before actually starting the implementation
- attempting to optimize the activity of content production, by imposing strong constraints on authors in order to standardize the format of textual contents and by providing them with a template based authoring tool
- standardizing the lay-out, by means of a variety of lay-out templates
- maintaining a data base of "building blocks", multimedia content and (automatically generated) hyperlinks
- using a modularized software architecture, based on a navigational engine and a presentation engine to aggregate the "building blocks" in the final application and incrementally populate it.

The "Polyptych" hypermedia system discussed in this paper is currently installed at the Poldi Pezzoli Museum in Milano, and in the museum house in Tuscany (Borgo San Sepolcro) where Piero della Francesca was born[1]; we are working on a more portable version on CD-ROM, which we plan to complete by the end of this year.

NOTES

1 It its current configuration, the application runs on a Pentium Multimedia PC, with 1024x768 screen resolution, with 65.000 colors; it includes

approximately 800 images, 20 minutes of sound, and requires 800 MB of hard disk space. In the CD-ROM version - under development - the screen resolution is 800x600 and the expected size will be reduce to 600 MB.

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