Annotating Illuminated Manuscripts: an Effective Tool for Research and Education

Maristella Agosti
agosti@dei.unipd.it

Nicola Ferro
nf76@dei.unipd.it

Nicola Orio
orio@dei.unipd.it

Department of Information Engineering
University of Padova
Via Gradenigo, 6/b – 35131 Padova, Italy

ABSTRACT

The aim of this paper is to report the research results of an ongoing project that deals with the exploitation of a digital archive of drawings and illustrations of historic documents for research and educational purposes. According to the results on a study of user requirements, we have designed tools to provide researchers with innovative ways for accessing the digital manuscripts, sharing, and transferring knowledge in a collaborative environment. We have found that the results of scientific research on the relationships between images of manuscripts produced over the centuries can be rendered explicit by using annotations. For this purpose, a taxonomy for linking annotation is introduced, together with a conceptual schema which represents annotations and links them to digital objects.

Categories and Subject Descriptors

H.3.7 [**Information Storage and Retrieval**]: Digital Libraries—*System issues*

General Terms

Design, Human Factors

Keywords

annotation, digital images, user requirements, education environment

1. INTRODUCTION

This paper reports research work on the feasibility of systems that manage image digital archives in ways that give to their professional final users the supports for annotating their content. The image digital archives of specific interest are those constituted by images taken from original *illuminated manuscripts*, which are books, usually handwritten, that include illustrations and, in the past centuries, were manually and artistically decorated with colours, gold, or silver.

The feasibility of a system which is able to store a digital archive of historical images and to manage related information, in particular in the case of images taken from illuminated manuscripts, usually has a two goals. The first goal represents the preservation of cultural heritage, because manuscripts tend to deteriorate in time, especially when not stored in a climate controlled environment: the digitization of historical images allows for separating the deterioration of the physical material from the deterioration of the information content. The second goal represents the dissemination of the historical material, because the content of a digital archive may be accessed by a wider community of users than a physical one: the content of digital archives can be available through a computer network, not to mention that in some cases users are not allowed to access the original manuscripts because of the risk of speeding up their deterioration.

There is a third aspect that plays an important role in the preservation and the dissemination of the cultural heritage. Illuminated manuscripts are still the subject of scientific research in different areas, namely art history and history of science, and all the disciplines that are related to their content – e.g., botany, astronomy, and medicine. To this aim, a digital archive of images needs to be enriched by a set of tools that enables researchers to study the development of scientific illustrations over the centuries. The design of these tools has to take into account that one of the goals of scientific research is dissemination of results for educational purposes. In this way, the digital archive can by used as a tool for both research and education.

This paper focuses on the feasibility study and the subsequent project of tools for scientific researchers on illuminated manuscripts. A special focus is given to manuscripts of scientific illustrations from the Middle Ages to the late Renaissance. Manuscripts may contain illustrations of plants, astrological and astronomical subjects, and parts of the human body. One of the aims of the research on this kind of manuscript regards the evolution of scientific representation and the relationships between different manuscripts that may bring to light possible influences among different authors. This aspect is of particular relevance for our institution, the University of Padova, because it has played a major role in the history of modern scientific illustrations. It was under the influence of Pietro d'Abano (1257-1315) that this Paduan school produced a number of illuminated man-

JCDL'05, June 7–11, 2005, Denver, Colorado, USA.

Figure 1: Images of illuminated manuscripts presented by the Ipsa prototype.

uscripts including botanical and medical illustrations, which were characterized by the high level of detail and by their realism, together with astronomical illustrations, which although based on ancient models were inspired by scientific criticism and not merely by astrology. For this reason, the University of Padova gave birth to an innovative approach to scientific representation, which was spread across Europe influencing the Western culture and had set the stage for the University of Padova's key role during the scientific revolution. However, the appeal of this imagery has to be related not only for science but also for its outstanding quality in terms of form and stylistic realization, which is of interest for both research and education of the fine arts.

The user requirement analysis, which has been carried out with a user-centered approach, plays a central role in the design because of the particular application domain. According to user requirements, the use of annotations has been proposed as a useful way of accessing a digital archive, sharing knowledge in a collaborative environment of researchers, and disseminating research results to students. Even if some of the presented results are tailored to the specific domain of illuminated manuscripts, the approach may be extended to other domains related to the exploitation and the preservation of cultural heritage.

The paper is structured as follows. Section 2 discusses related research work. Section 3 discusses and analyses user requirements. Section 4 describes how annotations enable users to carry out scientific research on the digital archive. Section 5 introduces the conceptual schema for modelling annotations. Section 6 gives conclusions.

2. RELATED WORK

As is well known, the preservation and the dissemination of cultural heritage is helping to promote the development of an increasing number of digital libraries and digital archives. The particular application to the cultural heritage domain poses interesting problems and challenges as reported in [15]. Some projects on digital libraries and digital archives pertain to illuminated manuscripts. The description of a digital archive of illuminated manuscripts is reported in [21], while [17] describes the digital library of a herbal – e.g., an illuminated manuscript that contain images of plants. Moreover, there is an increasing number of available systems on the market that give access to the digital version of manuscripts, incunabula, and old printed books.

We have already participated in a previous research project regarding the feasibility study of a digital archive for the preservation of the cultural heritage [3]. The feasibility study was about the creation of a digital archive of images of manuscripts of music scores, digitized versions in *Musical Instrument Digital Interface (MIDI)* format, and recordings of performances of music works by Venetian composers, as Benedetto Marcello (1686-1739) and Giovanni Pierluigi da Palestrina (1525/6-1594). The feasibility study was the motivation for a subsequent research project aimed at developing new ways of indexing and retrieving music documents in a digital library [29], both in symbolic [30] and in audio forms [31].

The particular field of illuminated manuscripts in the context of scientific illustration has already been addressed in the context of a research project at the University of Padova, named Ipsa. Figure 1 shows two screenshots of Ipsa prototype. The focus of this project has been the development of a digital archive of images of historical herbals. The study of herbals poses interesting research challenges for historians of the arts and science, due to the particular evolution of the representation of plants. During a great part of the Middle Ages authors of these illuminated manuscripts created

illustrations with an artistic flair rather than in its realistic form. Therefore, most of the illustrations were simply copies of previous works, with changes inspired by stylistic embellishments and not by naturalistic reasons. Thus, researchers were interested in highlighting explicitly these historical relationships between illustrations, which was an original outcome of the initial user study [2]. During the Ipsa project, an initial prototype system was developed for users testing and for collecting feedback both from researchers and students of history of science, history of arts, and botany.

With respect to the usage of annotations as a research tool in the humanities, Frommholz et. al [19] employ annotations to support collaboration between researchers on European historical film documentation (20's and 30's), such as historical film censorship records, press material, photos, film posters, digital film/video fragments. They make use of typed links, whose types have been empirically defined, in order to classify the interrelations between the annotations and the annotated documents. Furthermore, Frommholz et al. [19] and Thiel et al. [36] consider annotations – specifically annotations threads – as an extension of the document they belong to, which creates a discourse context. In the discourse context not only the annotation itself but also its position in the discourse and its type are exploited for searching and retrieving documents. This approach is revised and extended upon in [20] to probabilistic datalog. Finally, typed links are utilized also in [6] in order to define an hypertext between annotations and annotated documents, which is exploited for providing users with advanced search functionalities based on annotations. As a final remark, a lot of interesting work has been done regarding typed links and automatic link construction, such as [1, 4, 9, 14], but as of yet this is not applied to the field of annotations.

On the other hand, many user studies are aimed at understanding annotation practices and discovering common annotation patterns. Marshall [25] studied personal annotative practices of American college students in order to point out the form the annotations take on in the textbooks and in turn the function of the annotations derived from their form. Marshall [26] carries on her research work and categorizes annotations along several dimensions, that reflect the form which annotations may take on. Finally, the relationship among private, shared and public annotations and how they can be exploited to find useful passages in the text are investigated in [27, 28, 35].

3. USER REQUIREMENTS

The development of models and tools for researchers and scholars in the area of illuminated manuscripts requires a careful analysis of user requirements. It is likely that the requirements for carrying out scientific research will be more complex and articulated than requirements for common users. Common users access an image digital archive to acquire information in a given field, researchers access the archive to disclose knowledge and discover new relationships among digital objects.

Research users have been interviewed in a number of meetings, which involved art historians, historians of science, botanists, and astronomists. The first ideas about users requirements have been formalized in a draft proposal that has been presented and discussed with research users. Refinements of the proposal have been added, by reiterating the points of the meetings and the discussions. The results presented in this paper have been obtained after that research users tested a prototype version of the archive, and final comments have been collected and integrated in the model [8].

The management of a digital archive of illuminated manuscripts implies the development of tools for image processing and representation. In particular, there are a number of user requirements regarding image quality, transfer rate over a network, tools for zooming and analysing details and so on. The discussion of such tools is beyond the scope of this paper and it has been presented in [2], to which the interested reader may refer.

3.1 Disclosure of New Knowledge

One of the most important aims of the research on illuminated manuscripts of scientific illustration is the disclosure of hidden relationships between illustrations created by different authors. In particular, it is of primary importance for researchers to discover if illustrations have been copied from images of other manuscripts, if they have been merely inspired by previous works, or if they are directly inspired by nature. The disclosure of such a relationship between two images belonging to two manuscripts allows researchers to draw connections between the art of scientific illustration through the years and among different countries.

A major user requirement concerns the possibility of enriching the digital archive by highlighting explicit relationships that have been discovered by a researcher. In particular, a research user should be able to create *links* that connect one image to another that it is related to, in some way. It is important to keep in mind that images belong to different manuscripts and that their relationship may not be so obvious. Each disclosure of a relationship adds new information to the archive content, which should be shared with collaborators and students. The analysis of user requirements on link management has brought to light a number of advisable features that could be implemented.

- **Link authorship**: The creation of a link between two or more images depends on the scientific results of a researcher, who owns the intellectual rights to the disclosure of a new relationship between images; for this reason the author of each new link has to be recorded by the system.

- **Link typology**: Since two images can be related for a number of different reasons, the kind of relationship should be explicit. Different typologies of links are envisaged to express the possibility that an image is the progenitor of a set of other images, or that two images are a copy of one another, and so on.

- **Link symmetry**: Each typed link should have a symmetric link that is automatically generated by the system. For instance, if a link is added by a researcher because image **A** inspired image **B**, the system should add the information that image **B** has been inspired by image **A**.

- **Paths**: Links may form *historical paths* among images, because images in a manuscript can be copies of another one which in turn are copies themselves of previous illustrations; hence two images may not be

directly linked, because there is no direct relationship between them, but it could be possible to follow a path from one to the other by exploiting existing links.

It can be useful to clarify the notion of historical paths among images, because they turned out to be a major requirement of research users. A concept that has been introduced by researchers in the field of illuminated manuscripts is the one of *chains of derivation* among images. Each chain has a *progenitor*, which is an image that has been created through a direct examination of nature (i.e., a plant or a part of the human body). Subsequent authors, who accessed the manuscript containing that image, may have directly *copied* or may have been simply *inspired* by that image. These new images may in turn be copied or be the source of inspiration of other authors and so on, creating a chain of references to previous works. Clearly, it may have happened that a same progenitor gave rise to more than one chain, because two authors had independently copied the same image. The disclosure and the analysis of these chains of derivation aid in understanding how scientific culture spread through Europe and countries under the influence of Islamic culture, and the possibile contacts that different cultures may have had in the past.

3.2 Collaborative Environments for Researchers and Students

The study of illuminated manuscripts involves a number of researchers from different fields. For instance, herbals are of interest for both the art historian and the historian of science, yet they are of interest also for the botanist, because they represent plants and their possible variations through the centuries. Hence, the scientific research involves a number of persons with different expertise, who should be able to cooperate in order to share their knowledge and background. A digital archive of illuminated manuscripts has to provide a collaborative environment, where researchers should be able to interact and give different contributions on the definitions and redefinitions of objects and their relationships.

On the other hand, results in this research area should not be integrated in the digital archive, because there can be different and individual interpretations on the same collection of objects. Moreover, a researcher may prefer not to make his results public, if they have not yet been consolidated or even published. This means that each user, or each group of collaborators, should be able to maintain a personal view of the image digital archive content. In particular, the personalization should affect the relationships between images rather than the records stored in the archive because the latter are likely to be commonly accepted and may not vary that much over time.

The capability of giving different views on the same archive can be exploited also for educational purposes. In fact, students can access the same information with different approaches, taken from the individual results of each researcher. For instance, students may access the archive using the same approach used by an art historian and then compare this view with that of the historian of science. It can be noted that students may benefit also from the existence of different, and possibly contrasting, views of the same collection because these views reflect different critical approaches to the research about illuminated manuscripts.

4. ANNOTATING ILLUMINATED MANUSCRIPTS

The analysis of user requirements pointed out the need of tools for adding information about the relationships among objects. This goal can be achieved through the use of an annotation system that is built over an existing image digital archive. The main service provided by the annotation system consisting of a set of tools for image annotation. Annotations can be a useful aid for creating a collaborative environment, as reported in [24]. In our approach, a special focus is given to annotations that connect, or make a reference, from one image to another in the archive. We refer to this kind of annotations as *linking annotations*.

4.1 A Taxonomy for Linking Annotations

There are a number of different reasons that may point out a relationship between two images, depending on historical, aesthetical, and technical considerations. For this reason, we propose a taxonomy for linking annotations, which is divided in two classes. Because of the particular application domain, the proposed taxonomy cannot include links created by the author of a hypertext or automatically created by the system, as the one reported in [16].

The first link class reflects a *hierarchical* relationship between two images, where an image somehow depends on an earlier one. The annotation system automatically adds a symmetric linking annotation, in order to emphasize this dependency in both directions. According to the user requirements, there are three typologies of hierarchical relationship between two images, which are expressed by the following types.

- **A** `has_progenitor_in` **B**: image **B** is the first exemplar of a given representation of an object, from which a number of images, including **A**, descend as direct copies or as copies of intermediate representations.
- **A** `is_copy_of` **B**: the author of **A** used image **B** as his direct source of inspiration, both from the stylistic and from the pictorial point of view. **B** can either be the progenitor of **A** or an intermediate representation between **A** and its progenitor.
- **A** `is_elaboration_of` **B**: image **A** has been inspired by **B**, but there are a number of differences between the two that show that the author of **A** added personal changes to the original representation.

The second link class reflects a *relatedness* relationship between two images, because they share similar properties even though they have been created independently. Also in this case, the system automatically adds a symmetric annotation, in order to emphasize the relationship in both directions. According to researchers, there are three motivations by which two images can be related, even if there is no hierarchical relationship between them.

- **A** `has_same_model_of` **B**: images **A** and **B** descend from the same progenitor, even though they have been independently created by their authors. This kind of link tells us that **A** and **B** belong to two chains of derivations, which share the same progenitor.
- **A** `is_similar_to` **B**: although the two images are visually similar, it is not possible to draw a hierarchical

relationship between the two or to state that they descend from the same model. The existence of this link may help researchers and students to discard apparent hierarchical relationships and it has been proved that they do not exist.

- **A** `is_connected_to` **B**: sometimes a possible connection is not completely clear from the images themselves but instead we need to exploit additional information, such as knowledge on authors background and connections or their belonging to similar schools of scientific representation. This kind of link, which express a generic relationship, helps to point out that the relationship between **A** and **B** needs further investigation.

The presence of a hierarchical structure can be exploited by automatically discovering *paths* across the hypertext given by the link structure. For instance, paths may describe the creation over the years of copies of a renowned author, and the subsequent creation of copies of the copies and so on. At the same time, paths can describe the dissemination of a particular approach to scientific representation over time and space. On the other hand, relatedness links may be useful to disclose similarities between images, because together with hierarchical links they may introduce a notion of distance between each couple of images. Researchers may discover new similarities because two images, even if not directly connected, are very close in the graph structure induced by links.

The proposed taxonomy has been derived from the conducted analysis and design of users requirements. The effort involved in this research has been to identify the primitive types of link necessary to make all the relationships that are of interest for the researchers and students explicit. In particular, it has been considered that the annotation of a digital archive is an ongoing process, which depends on the results of scientific research, and the link structure can be continuously modified by a researcher. This taxonomy is sufficient to build a directed graph structure on the digital archive which can be used to discover the chains of derivation among images. A positive side effect of this design choice it that a reduced amount of link typologies helps researchers to be consistent in their choices of use of link types.

4.2 User Views

After a user has added his personal knowledge on the application domain by drawing typed links between images, the digital archive is dynamically enriched by a hypertextual structure. Each researcher may then access in different ways to the digital archive, because each user may have his own view on the archive, which is given by the hypertextual structure. The existence of such a structure can integrate direct search through navigation inside the image collection. If a mechanism of information sharing inside a user group is provided, as the ones applied to collaborative environments, researchers may cooperate in their study on illuminated manuscripts by sharing the information on relationships between different sources. The annotations can be private, shared among a group of collaborators or public.

As an example, let us suppose that a cooperative group is formed an it also contains an art historian and a botanist. The botanist may have identified a relationship between two different images of plants, because the leaves drawn on one image are not realistic because they are too similar to those of another plant. The art historian can use this information to disclose a new historical path connecting the two images. It is likely that also other users apart from researchers would benefit from the presence of an hypertextual structure. For instance, students may not be able to effectively search the digital archive for a specific image. While, on the other hand, they can find the needed image by using the navigation paradigm if links to that image exist.

Figure 2 shows an example of a personalized user view on some linked images. Users may benefit from the visualization of both hierarchical and relatedness relationships among images.

5. MODELLING OF ANNOTATIONS

Figure 3 show the conceptual schema for annotations we propose in order to enable the described features. It is centred around two main point: how to model annotations and how to connect them to images. The next sections describe these two points in more detail.

5.1 How to Model Annotations

The ANNOTATION entity represents the abstraction of the annotation, i.e. it expresses the existence of an object capable of annotating another object, without having to specify its characteristics any further. This is the pivotal entity, which provides the basis for modelling annotations.

The ANNOTATION entity has the following attributes: `ID` is a unique identifier for the annotation, e.g. an *Uniform Resource Identifier (URI)* [10] or a *Digital Object Identifier (DOI)* [32]; `Created` and `Modified` represent, respectively, the creation date and the last modified date of the annotation; and `Scope` specifies if the annotation is private, shared, or public.

In order to fully capture the annotation, we need to introduce the distinction between the *sign of annotation*, which is the way an annotation takes shape, such as a piece of text or some graphic mark, and the *meaning of annotation*, which explains the semantics of a sign of annotation [5, 7]. In conclusion, an annotation is expressed by one or more signs of annotation, that in turn are characterised by one or more meanings of annotation, thus defining the overall semantics of the annotation.

The choice of explicitly distinguishing between the meaning and the sign of annotation is quite new in the field of annotations. Indeed, annotations are generally typed as a whole according to some pre-defined set of annotation types [11, 13, 19, 23], but there is usually no means for describing the semantics of an annotation with the desired level of precision, whereas this is possible with the meanings of annotation. Furthermore, annotation types do not allow any kind of navigation among different types, while meanings of annotation can be organized in order to provide such facility of use.

Some interesting insights about the choice of distinguishing between meaning and sign of annotation can be gained from the field of *Human Computer Interaction (HCI)*. Indeed, [12] deals with visual languages and defines *Characteristic Structures (CSs)* as sets of image pixels forming functional or perceptual units whose recognition results in the association of that CS with a meaning. Then, [12] call *Characteristic Patterns (CPs)* the CSs along with descriptions of the CSs and a relation that associates descriptions to CSs and viceversa. The distinction between CSs and CPs

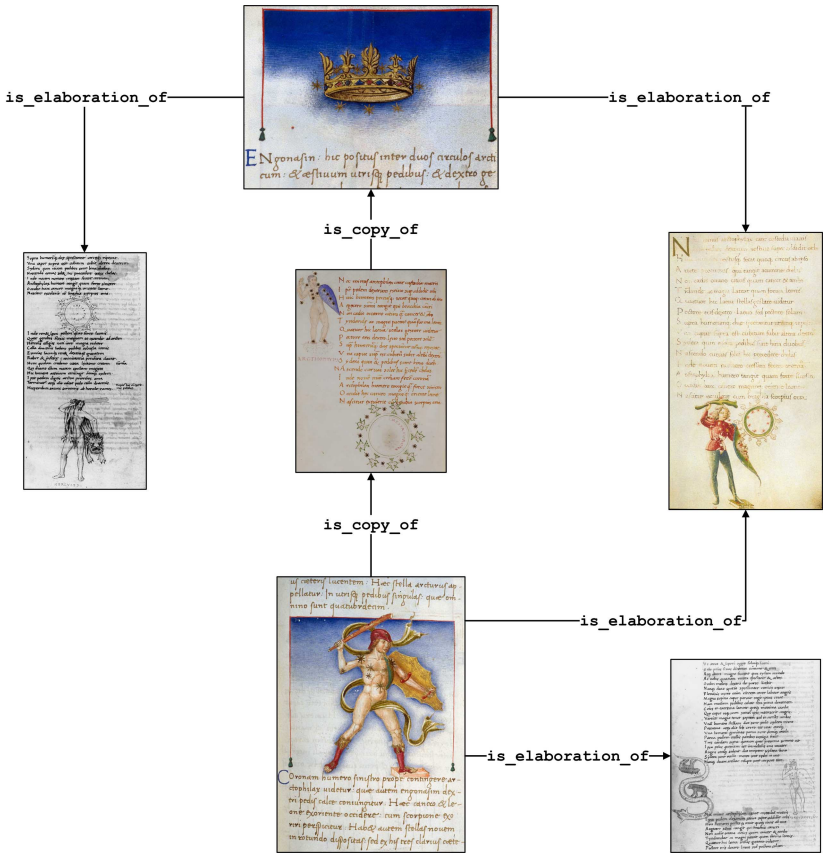

Figure 2: Example of a personalized view on some linked images.

resembles the distinction between sign and meaning of annotation; also [18] recognizes this correspondence and says that "an annotation is a complex CS interpreted by a human as a CP". On the other hand, [13] adopts the CSs and CPs mechanism in the context of annotations too, but this mechanism is used in order to place annotations on information resources rather than to distinguish between the semantics and the materialization of annotations.

Thus, the ANNOTATION entity is coupled with the two other entities MEANING and SIGN, respectively representing the meaning of annotation and the sign of annotation.

The MEANING entity is characterised by a unique identifier, called `ID`, and also by a `Description` attribute, which describes the meaning of annotation. On the MEANING entity there is a recursive relationship, called CONTAIN, that expresses the existence of both broader and narrower meanings. Thus, the meanings of annotation can be organised into some sort of hierarchy. Subsequently, some navigation facilities within this hierarchy can be provided to the user. The CONTAIN relationship expresses the fact that a meaning may be contained in one or more meanings and that it may contain one or more meanings. In addition, CONTAIN allows us to define a graph of meanings of annotation. The `Label` attribute describes the kind of relationship between two meanings of annotation, if necessary. In conclusion, this is the basic mechanism for carrying out the link taxonomy, introduced in Section 4.1. Note that the MEANING entity and the CONTAIN relationship allow us to define the taxonomy in an extensible way, so that new link types can be easily added in a consistent way, if necessary.

The SIGN entity has an unique identifier, called `ID`, and a `Content` attribute, which represent the actual content of the sign of annotation, e.g. a piece of text or an image. The SIGNTYPE entity describes the kind of a sign of annotation, e.g. a textual sign or a graphic sign, and makes it possible to correctly interpret the `Content` attribute of a SIGN entity. The SIGNTYPE entity is connected to the SIGN entity by means of the TYPIFY relationship, which expresses the fact that a SIGN must have exactly one SIGNTYPE, while a SIGNTYPE may specify one or more SIGN entities.

Two relationships, called EXPRESS and MEAN, allow the three entities ANNOTATION, MEANING and SIGN to work together in order to define the semantics and the materialization of an annotation.

The EXPRESS relationship denotes that an ANNOTATION entity has to be expressed by one or more SIGN entity, and that a given SIGN entity has to be employed one and only one time in order to express an ANNOTATION entity. The attributes of EXPRESS allow us to physically identify the part of the *Digital Object (DO)* which has to be annotated. In particular, the `Pointer` attribute identifies a portion of a DO, e.g. it could be an XPath expression when using an *eXtensible Markup Language (XML)* document; the `Offset` attribute selects a starting offset with respect to the portion identified by `Pointer`, e.g. the initial character within an XML element; finally, the `Extent` attribute specifies the size

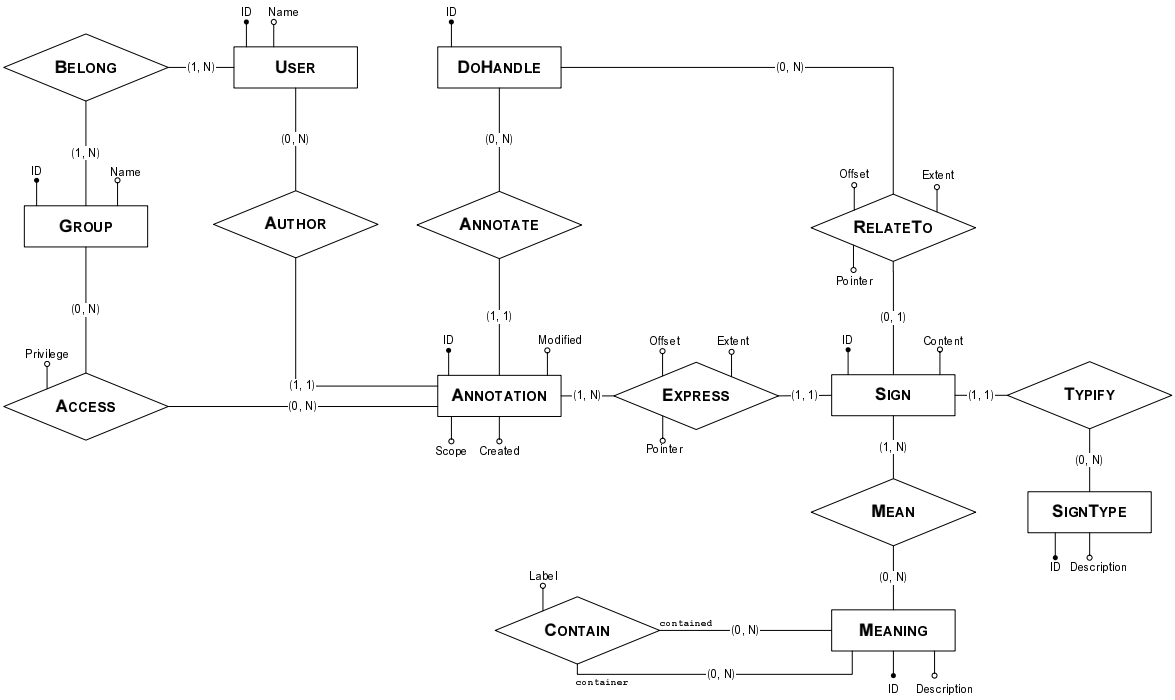

Figure 3: Entity–Relationship schema for modelling annotations.

of the sign of annotation, e.g. the number of characters that are annotated within the portion identified by `Pointer` starting from `Offset`.

The MEAN relationship expresses the fact that a SIGN entity has to be related to one or more MEANING entities and that a MEANING entity may characterise one or more SIGN entities.

5.2 How to Link Annotations to Digital Objects

As explained in the previous section, the ANNOTATION entity represents the abstraction of an object capable of annotating another object. In order to connect annotations to DOs we also need an entity that represents the abstraction of an object that can be annotated. This entity is called DOHANDLE and represents a DO by means of using a handle to identify it. This choice is coherent with what has been made by [22, 33] who refer to and compose DOs only by identifiers and annotate them with metadata from a taxonomy of terms. Thus, the starting points for connecting annotations to DOs are the ANNOTATION and DOHANDLE entities which represents the fact that there are two kinds of related objects: DOs that can be annotated and annotations that annotate those DOs.

The relationship between annotations and annotated DOs is represented by the ANNOTATE relationship, which links an ANNOTATION entity to the DOHANDLE entity that it annotates. This relationship expresses the fact that an annotation must annotate one and only one DO and that a DO may be annotated by one or more annotations.

Once we have annotated a DO, the annotation itself can be considered as a DO eligible to be annotated. Thus, the conceptual schema has the following additional constraint: once the annotation has been created, an occurrence of the DOHANDLE entity corresponding to the annotation have to be added, in order to allow the newly created annotation to be annotated as well. Users can therefore create not only sets of annotations concerning a DO, but also threads of annotations, i.e. annotations which reply to one another. These threads of annotations are the basis for actively involving users with the system and for enabling collaboration. It is worth noting that this mechanism allows us to carry out the notions of *historical paths* and *chain of derivation*, introduced in Section 3. Indeed, on the same DO many different threads of annotations, that are just chains of derivation, can insist.

The RELATETO relationship is used for the purpose of relating the annotation to other DOs. The RELATETO relationship associates a sign of annotation with the DO it refers to. In addition, the RELATETO relationship allows a SIGN entity to refer or not to a DO, while a DO may be referred to by one or more signs of annotation. The attributes of RELATETO have the same meaning of the attributes of EXPRESS.

On the whole, the ANNOTATE relationship specifies the origin of the link and the RELATETO relationship identifies the destination of the link. Note that not only links can be typed by using the MEANING entity, but they can also have a content by using the SIGN entity. In conclusion, the *Entity–Relationship (ER)* schema allows us to exploit annotations as if they were typed links able to carry additional information or data. Figure 4 shows how annotations can be effectively employed in order to carry out the example depicted in Figure 2: annotations link images together, where the ANNOTATE relationship identifies the source image and the RELATETO relationship points to the destination image;

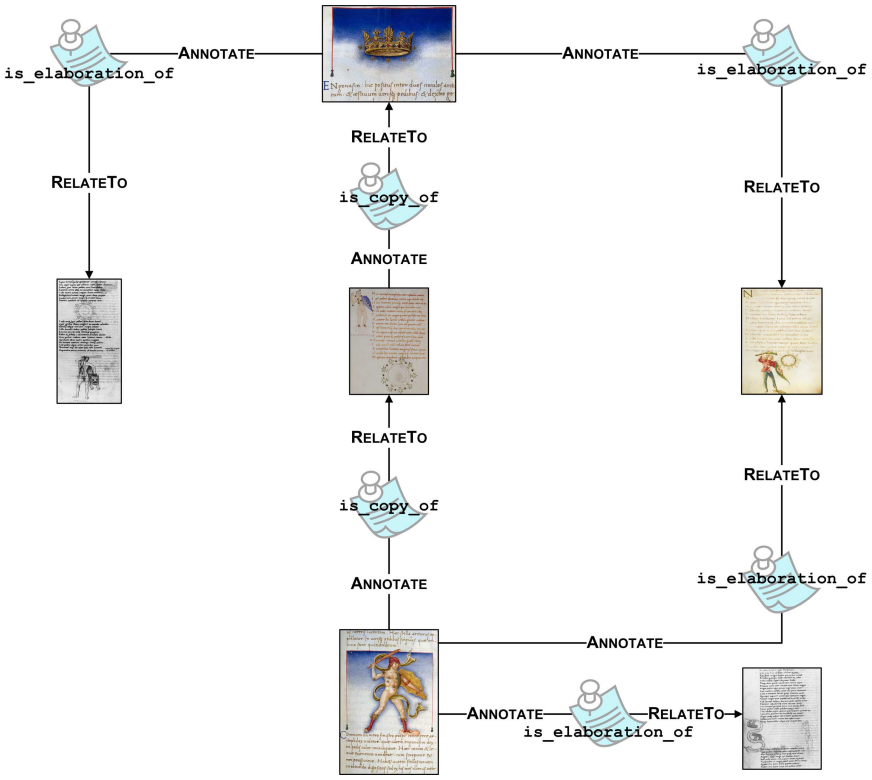

Figure 4: Example of a personalized view on some linked images by using annotations.

furthermore, the annotation is typed according to the link types introduced in Section 4 by using the MEANING entity and it could also contain additional contents and information, if necessary.

The USER entity represents a user, granted by the system. The AUTHOR relationship relates an annotation with its author; a user may create one or more annotations, while an annotation must be created by one and only one user.

Finally, the GROUP entity represents a users' group, related to users by means of the BELONG relationship: the USER entity has to belong at least to one GROUP of user – or more, if necessary – and a GROUP entity contains one or more USER. The ACCESS relationship allows an ANNOTATION entity to be shared by one or more groups of users, and a GROUP may share one or more ANNOTATION entities. The ACCESS relationship has the `Privilege` attribute, which specifies the privileges, e.g. read or modify, granted to a GROUP sharing the annotation. In conclusion, the USER and GROUP entities allow us to describe the different layers of annotations that personalize the digital archive.

The proposed conceptual schema is quite innovative, because it describes the annotation with an extent of detail not present in other similar proposals. Furthermore, it provides us with great flexibility, due to the fact that we can express the different aspects of an annotation and even couple them together. In addition, this does not constrain us to fixed types of annotations. Thus, our proposal represents an enhancement and a generalization with respect to the models proposed by [23, 34]. Finally, being a conceptual schema, our model can be easily mapped to different models, such as a relational schema, a *Resource Description Framework (RDF)* schema or a XML schema; this way it provides us with great flexibility when dealing with different architectural choices.

6. CONCLUSIONS

This paper reports the results on a study carried out to support the scientific research on illuminated manuscripts, and the dissemination of cultural heritage for educational purposes. In fact, digital archives of illuminated manuscripts can be a viable tool for research and education, providing that some functionalities are designed and developed. To this aim, a wide range user requirement analysis has been carried out. According to the results of the analysis, annotations are shown to be useful for explicitly expressing the relationships between objects in the digital archive. A taxonomy of links has emerged from the study, which allows for indicating the different relationships that may connect digital objects, and a modeling tool for annotations has been presented.

Linking annotations are proposed as a tool for researchers working in a collaborative environment. In particular, linking annotations can be a valuable tool for representing the evolution of scientific representations over the past centuries. It is believed that the proposed approach can be extended also to other application domains, in particular in the field of preservation and dissemination of cultural heritage. To this end, future research work will concern the study and development of methods for automatically inferencing relationships among the link types of the proposed taxonomy. Note that the model for annotations, presented in Section 5,

is flexible enough to support extensions and processing of the link taxonomy. Furthermore, this flexibility allows us to anticipate future user needs which may emerge later on; for example, our model for annotations provides us with a tool for adding multimedia content, such as textual comments or graphic marks, to the different linking annotations.

The actual prototype system, which already contains hundreds of images with an increasing number of linking annotations, will be the basis for the development of a new release of the digital archive. The new version of the archive will be used to carry out a more formal evaluation of the effectiveness of the linking mechanism.

Acknowledgments

The authors wish to thank the coordinator of the Ipsa project, professor Maria Giordana Canova, of the Faculty of Humanities of the University of Padova, for the useful discussions on different aspects of the illuminated manuscripts. Many thanks to Lucio Benfante, who developed the initial prototype version of the digital archive and of the annotation system.

This work was partially funded by ECD (Enhanced Contents Delivery), a joint program between the Italian National Research Council (CNR) and the Ministry of Education (MIUR), by law 449/97-99, and partially supported by the DELOS Network of Excellence on Digital Libraries, as part of the Information Society Technologies (IST) Program of the European Commission (Contract G038-507618).

7. REFERENCES

[1] M. Agosti and J. Allan. Introduction to the Special Issue on Methods and Tools for the Automatic Construction of Hypertext. *Information Processing & Management*, 33(2):129–131, March 1997.

[2] M. Agosti, L. Benfante, and N. Orio. IPSA: A Digital Archive of Herbals to Support Scientific Research. In T. M. T. Sembok, H. B. Zaman, H. Chen, S. R. Urs, and S. H. Myaeng, editors, *Proc. 6th International Conference on Asian Digital Libraries. Digital Libraries – Digital Libraries: Technology and Management of Indigenous Knowledge (ICADL 2003)*, pages 253–264. Lecture Notes in Computer Science (LNCS) 2911, Springer, Heidelberg, Germany, 2003.

[3] M. Agosti, F. Bombi, M. Melucci, and G. Mian. Towards a digital library for the Venetian music of the eighteenth century. In J. Anderson, M. Deegan, S. Ross, and S. Harold, editors, *DRH 98: Selected papers from Digital Resources for the Humanities*, pages 1–16. Office for Humanities Communication, 2000.

[4] M. Agosti, F. Crestani, and M. Melucci. On the Use of Information Retrieval Techniques for the Automatic Construction of Hypertext. *Information Processing & Management*, 33(2):133–144, March 1997.

[5] M. Agosti and N. Ferro. Annotations: Enriching a Digital Library. In T. Koch and I. T. Sølvberg, editors, *Proc. 7th European Conference on Research and Advanced Technology for Digital Libraries (ECDL 2003)*, pages 88–100. Lecture Notes in Computer Science (LNCS) 2769, Springer, Heidelberg, Germany, 2003.

[6] M. Agosti and N. Ferro. Annotations as Context for Searching Documents. In F. Crestani and I. Ruthven, editors, *Proc. 5th International Conference on Conceptions of Library and Information Science – Context: nature, impact and role*, (in print), 2005.

[7] M. Agosti, N. Ferro, I. Frommholz, and U. Thiel. Annotations in Digital Libraries and Collaboratories – Facets, Models and Usage. In R. Heery and L. Lyon, editors, *Proc. 8th European Conference on Research and Advanced Technology for Digital Libraries (ECDL 2004)*, pages 244–255. Lecture Notes in Computer Science (LNCS) 3232, Springer, Heidelberg, Germany, 2004.

[8] M. Agosti, N. Ferro, and N. Orio. Annotations as a Support to Research Users. In *Proc. 7th International Workshop of the EU Network of Excellence DELOS on Audio-Visual Content and Information Visualization in Digital Libraries (AVIVDiLib'05)*, (in print), 2005.

[9] J. Allan. Automatic Hypertext Link Typing. In D. Stotts, editor, *Proc. 7th ACM Conference on Hypertext and Hypermedia (HT 1996)*, pages 42–52. ACM Press, New York, USA, 1996.

[10] T. Berners-Lee, R. Fielding, U. C. Irvine, and L. Masinter. Uniform Resource Identifiers (URI): Generic Syntax. RFC 2396, August 1998.

[11] P. Bottoni, R. Civica, S. Levialdi, L. Orso, E. Panizzi, and R. Trinchese. MADCOW: a Multimedia Digital Annotation System. In M. F. Costabile, editor, *Proc. Working Conference on Advanced Visual Interfaces (AVI 2004)*, pages 55–62. ACM Press, New York, USA, 2004.

[12] P. Bottoni, M. F. Costabile, and P. Mussio. Specification and Dialogue Control of Visual Interaction through Visual Rewriting Systems. *ACM Transactions on Programming Languages and Systems (TOPLAS)*, 21(6):1077–1136, November 1999.

[13] P. Bottoni, S. Levialdi, and P. Rizzo. An Analysis and Case Study of Digital Annotation. In N. Bianchi-Berthouze, editor, *Proc. 3rd International Workshop on Databases in Networked Information Systems (DNIS 2003)*, pages 216–230. Lecture Notes in Computer Science (LNCS) 2822, Springer, Heidelberg, Germany, 2003.

[14] J. H. Coombs. Hypertext, Full Text, and Automatic Linking. In J.-L. Vidick, editor, *Proc. 13th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval (SIGIR 1990)*, pages 83–98. ACM Press, New York, USA, 1990.

[15] G. Crane. Cultural heritage digital libraries: Needs and components. In M. Agosti and C. Thanos, editors, *Proc. 6th European Conference on Research and Advanced Technology for Digital Libraries (ECDL 2002)*, pages 626–637. Lecture Notes in Computer Science (LNCS) 2458, Springer, Heidelberg, Germany, 2002.

[16] S. DeRose. Expanding the notion of links. In R. Akscyn, editor, *Proc. 2nd Annual ACM Conference on Hypertext (HT 1989)*, pages 249–257. ACM Press, New York, USA, 1989.

[17] A. Don, L. Teodosio, J. Lambert, and D. Atchley. From generation to generation: multimedia,

community and personal stories. In M. Blattner and J. Limb, editors, *Proc. 2nd ACM International Conference on Multimedia (MM 1994)*, pages 337–338. ACM Press, New York, USA, 1994.

[18] D. Fogli, G. Fresta, and P. Mussio. On Electronic Annotation and Its Implementation. In M. F. Costabile, editor, *Proc. Working Conference on Advanced Visual Interfaces (AVI 2004)*, pages 98–102. ACM Press, New York, USA, 2004.

[19] I. Frommholz, H. Brocks, U. Thiel, E. Neuhold, L. Iannone, G. Semeraro, M. Berardi, and M. Ceci. Document-Centered Collaboration for Scholars in the Humanities – The COLLATE System. In T. Koch and I. T. Sølvberg, editors, *Proc. 7th European Conference on Research and Advanced Technology for Digital Libraries (ECDL 2003)*, pages 434–445. Lecture Notes in Computer Science (LNCS) 2769, Springer, Heidelberg, Germany, 2003.

[20] I. Frommholz, U. Thiel, and T. Kamps. Annotation-based Document Retrieval with Four-Valued Probabilistic Datalog. In R. Baeza-Yates, Y. Maarek, T. Roelleke, and A. P. de Vries, editors, *Proc. 3rd XML and Information Retrieval Workshop and the 1st Workshop on the Integration of Information Retrieval and Databases (WIRD2004)*, pages 31–38. `http://homepages.cwi.nl/~arjen/wird04/wird04-proceedings.pdf` [last visited 2005, April 5], 2004.

[21] H. Gladney, F. Mintzer, F. Schiattarella, J. Bescós, and M. Treu. Digital access to antiquities. *Communications of the ACM*, 41(4):49–57, April 1998.

[22] B. Gueye, P. Rigaux, and N. Spyratos. Taxonomy-Based Annotation of XML Documents: Application to eLearning Resources. In G. A. Vouros and T. Panayiotopoulos, editors, *Proc. 3rd Helenic Conference on AI – Methods and Applications of Artificial Intelligence (SETN 2004)*, pages 33–42. Lecture Notes in Computer Science (LNCS) 3025, Springer, Heidelberg, Germany, 2004.

[23] J. Kahan and M.-R. Koivunen. Annotea: an open RDF infrastructure for shared Web annotations. In V. Y. Shen, N. Saito, M. R. Lyu, and M. E. Zurko, editors, *Proc. 10th International Conference on World Wide Web (WWW 2001)*, pages 623–632. ACM Press, New York, USA, 2001.

[24] D. Lawton and I. Smith. The knowledge weasel hypermedia annotation system. In S. E. Poltrock, editor, *Proc. 5th ACM Conference on Hypertext (HT 1993)*, pages 106–117. ACM Press, New York, USA, 1993.

[25] C. C. Marshall. Annotation: from Paper Books to the Digital Library. In R. B. Allen and E. Rasmussen, editors, *Proc. 2nd ACM International Conference on Digital Libraries (DL 1997)*, pages 233–240. ACM Press, New York, USA, 1997.

[26] C. C. Marshall. Toward an Ecology of Hypertext Annotation. In R. Akscyn, editor, *Proc. 9th ACM Conference on Hypertext and Hypermedia (HT 1998): links, objects, time and space-structure in hypermedia systems*, pages 40–49. ACM Press, New York, USA, 1998.

[27] C. C. Marshall and A. J. B. Brush. From Personal to Shared Annotations. In L. Terveen and D. Wixon, editors, *Proc. Conference on Human Factors and Computing Systems (CHI 2002) – Extended Abstracts on Human Factors in Computer Systems*, pages 812–813. ACM Press, New York, USA, 2002.

[28] C. C. Marshall and A. J. B. Brush. Exploring the Relationship between Personal and Public Annotations. In H. Chen, H. Wactlar, C.-C. Chen, E.-P. Lim, and M. Christel, editors, *Proc. 4th ACM/IEEE-CS Joint Conference on Digital Libraries (JCDL 2004)*, pages 349–357. ACM Press, New York, USA, 2004.

[29] M. Melucci and N. Orio. Combining melody processing and information retrieval techniques: Methodology, evaluation, and system implementation. *Journal of the American Society for Information Science and Technology*, 55(12):1058–1066, October 2004.

[30] G. Neve and N. Orio. Indexing and retrieval of music documents through pattern analysis and data fusion techniques. In X. Serra and M. Leman, editors, *Proc. 5th International Conference on Music Information Retrieval (ISMIR 2004)*, pages 216–223. Universitat Pompeu Fabra, 2004.

[31] N. Orio. Alignment of performances with scores aimed at content-based music access and retrieval. In M. Agosti and C. Thanos, editors, *Proc. 6th European Conference on Research and Advanced Technology for Digital Libraries (ECDL 2002)*, pages 479–492. Lecture Notes in Computer Science (LNCS) 2458, Springer, Heidelberg, Germany, 2002.

[32] N. Paskin, editor. *The DOI Handbook – Edition 4.2.0*. International DOI Foundation (IDF). `http://www.doi.org/hb.html` [last visited 2005, April 5], February 2005.

[33] P. Rigaux and N. Spyratos. Metadata Inference for Document Retrieval in a Distributed Repository. In M. J. Maher, editor, *Proc. 9th Asian Computing Science Conference – Advances in Computer Science (ASIAN 2004) – Higher Decision Making. Dedicated to Jean-Louis Lassez on the Occasion of His 5th Cycle Birthday*, pages 418–436. Lecture Notes in Computer Science (LNCS) 3321, Springer, Heidelberg, Germany, 2004.

[34] T. Sannomiya, T. Amagasa, M. Yoshikawa, and S. Uemura. A framework for sharing personal annotations on web resources using XML. In M. E. Orlowska and M. Yoshikawa, editors, *Proc. Workshop on Information Technology for Virtual Enterprises*, pages 40–48. IEEE Computer Society Press, 2001.

[35] F. Shipman, M. N. Price, C. C. Marshall, and G. Golovchinsky. Identifying Useful Passages in Documents based on Annotation Patterns. In T. Koch and I. T. Sølvberg, editors, *Proc. 7th European Conference on Research and Advanced Technology for Digital Libraries (ECDL 2003)*, pages 101–112. Lecture Notes in Computer Science (LNCS) 2769, Springer, Heidelberg, Germany, 2003.

[36] U. Thiel, H. Brocks, I. Frommholz, A. Dirsch-Weigand, J. Keiper, A. Stein, and E. J. Neuhold. COLLATE – A collaboratory supporting research on historic European films. *International Journal on Digital Libraries*, 4(1):8–12, August 2004.