A self organizing map (SOM) extended model for information discovery in a digital library context

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ABSTRACT
This paper presents the MicroNOMAD Discovering Tool. Its main characteristic is both to provide an user with emergent analyses of a multimedia database content and with querying and browsing guidelines through the use of an advanced topographic interface model. The model also allows the user to dynamically exploit semantic exchanges between multiple viewpoints on the database. The tool basic principles are firstly described. A tool experimentation which is achieved on the multimedia data-base associated to the BIBAN"Art Nouveau" server is then developed. It clearly demonstrates that the combination of both the topographic structures, the textual and iconographic interaction, and the viewpoint exchanges proposed by the MicroNOMAD core model could play an essential role in several discovering and browsing processes.

Keywords
multimedia, information discovery, classification, neural networks, data visualization, information retrieval

1. INTRODUCTION
Digital Libraries are generally requested to provide access to a large variety of information. As a result, most of DL architectures are issued from Information Retrieval models and are designed to help end-users in retrieving information «he already knows but he has lost a link to». Then, a kernel strategy of many available systems or search engines consists in asking a user to formulate a preliminary query, as an initiate value, and to start an inter-active process of reformulation. From an users point of view there is a risk that he will quickly get lost if he has been too generic or imprecise. We therefore aim at building Information Discovering Systems rather than Information Retrieval Systems. Indeed, we want to give some ways for exploring the knowledge of a corpus. In other words, we would like to answer questions like this: «what is the most important feature in this topic? what's new? what do I not know in this domain? etc.». We further worked on textual «Digital Libraries» in the framework of two projects dealing with biomedical information: MedExplore and WebStress. These experiences have shown that a complex exploration requires the user to handle a fairly big set of various tools. Moreover, these tools are selected in a «non predictable» order, depending on the intermediate results. Thus, the user needs a fast and global analysis of intermediate data. In that context, images, graphics and iconographic resources have appeared to be a very fundamental component in man-machine interface. For instance, when the system delivers to an user a list of titles, the user needs to read the abstracts to determine whether the topic is relevant or not; let us mention that a fast glance is sufficient on an image to achieve this. To build up our own Information Discovering System turning to account this "outstanding explanatory power" of the images, we have experienced a specific approach which led to the MicroNOMAD Discovering Tool. The core model of that tool strongly derives from the multimap topographic model which has been successfully tested on textual data in the framework of the NOMAD IR System [10]. This latter model, which can be itself considered as a extension of the basic Kohonen topographic map model, enables the user to browse through a documentary database by means of an advanced topographic interface. The MicroNOMAD core model added-value is then mainly to develop a synergy between the browsing and discovering capabilities of the NOMADs original multimap model, on the one hand, and the natural capability of the imbedded Kohonen map model to support at the same time concept mapping and image mapping, on the other hand. In a first part we will briefly describe our previous research. In a second part, we will explain the basics of our new Discovering Tool and we will conclude with experiments on this tool.

Proceedings of the International Workshop on Multimedia Data Mining (MDM/KDD'2000), in conjunction with ACM SIGKDD conference. Boston, USA, August 20, 2000
(O.R. Zaïane, S.J. Simoff, eds.)

2. THE BIBAN PROJECT
BIBAN (Bibliographic and Iconographic and Base Art Nouveau) is a research prototype for iconographic Digital Libraries. BIBAN is an application of a generic XML workbench DILIB [3] and has been designed for investigating Digital Libraries containing images and heterogeneous documents in a multilingual context. BIBAN covers the "Art Nouveau" period, a widespread movement for a renewal of the decorative art at the end of 19th century. BIBAN's content includes:

- a set of electronic books in French with their translation in English and German: each book keeps its own style and is implemented as a individual web server (with several HTML pages). One of them is «Nancy and the Art Nouveau Style» [6] which deals with the collections of «Musée de l'Ecole de Nancy».
- an iconographic base: this base contains a set of images. A metadata record which, coded with an elementary XML schema, is made for each image.
- a bibliographic base: this base is a subset (300 references) of BHA (Biblographie de l'Histoire de l'Art) selected by «Art Nouveau» or «Ecole de Nancy». This bibliography is connected with a much larger set (6000 references) randomly extracted from the whole BHA.

All documents are indexed with BHA search entries. Thus, the same description vocabulary is used for images, bibliographic records and pages of electronic books. To this end, each HTML page contains Dublin Core [18] elements.

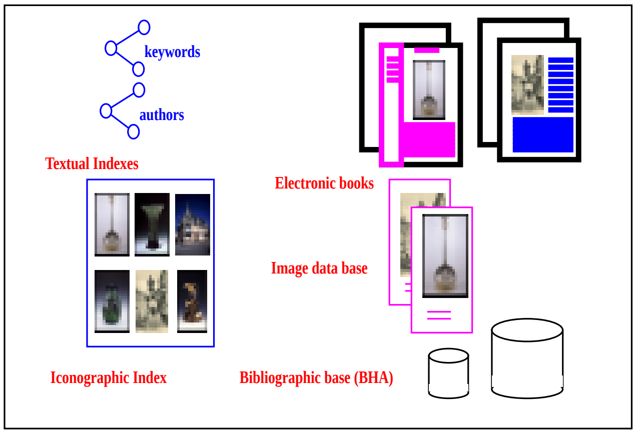

Figure 1: BIBAN context

We have put an early version of the BIBAN server on the INTERNET with a limited advertising, mainly intended for information specialists. BIBAN was put on the Web without any kind of assistance, by people with a poor knowledge of the domain. As a result, one important point was raised: the iconographic tools we have provided in this first experiment have been intensively used during browsing and querying steps. Nevertheless, these tools were mainly based on elementary text to image links or image to image links. They appeared to be useful for widening a query but not sufficient for giving a global view of the main topics of a collection and their relationships. We have then implemented a new set of techniques for producing structured iconographic maps. This point will be developed in the further paragraph.

3. ADAPTIVE MODEL

3.1 Introduction

The implementation of the IR process on iconographic databases considering the specificities of the images has been tackled through time with a lot of different approaches.

On one hand, in some early approaches, as the one proposed in the RIVAGE prototype [2], as well as the one more recently adopted for the first BIBAN prototype, the implementation of the concept of image mosaic or 2D mapping of images has been considered as a convenient way to give the user an overall view of its query results and moreover to help him in its relevance judgments. These approaches rely on the psychological facts that, conversely to textual information, the interpretation and judgment on a relatively large image set could easily be performed in one pass on such a mosaic by an user, without any explicit information on the image content. The early IDIM prototype described by Aigrain and al. [1] has gone one step further on this latter way, proposing a more categorical approach in which the user IR session on a iconographic database is reduced to an user multidirectional browsing through a 3x3 evolutive image mosaic. Conversely to the preceding models, one of the most interesting characteristics of this model is the very exploitation of the 2D structure of the image mosaic for defining different research directions based themselves on different background keywords classification profiles. Nevertheless, the lack of any access to this latter background information often led the user to make arbitrary choice in its browsing.

On the other hand, the use of alternative profiles like visual indexes for image description has been thoughtfully investigated these latter years [5]. Even if these approaches seem to be promising they surely could not cover all the user needs in an image retrieval process. These points have also been noticed by Duffing and al. [4]. Indeed, their original contribution consists in combining an image classification based on visual indexes and another one based on keyword indexes for computing the result of an user query. Unfortunately, their model do not at all rely on an image mosaic approach.

We found an interesting challenge in the trial of both combining the advantages of all the preceding models (i.e. image mosaic mapping, 2D structure exploitation, and multiple classification use) and dealing with advanced discovery capabilities through a federating approach. We therefore choose to derive our approach, which we called MicroNOMAD, from the topographic multimap model of the NOMAD IR System [9]. The role of the NOMAD's topographic multimap model is both to provide an user with emergent and «easy to use» analyses of a documentary database contents and with overall querying and browsing guidelines through an advanced topographic interface. Conversely to a lot of other more classical models, the NOMAD model allows the user to exploit dynamic exchanges between multiple viewpoints (i.e classifications) on the database, those being implemented through Said exchanges could be used in several ways. For instance, they enable an user to highlight semantic correlation between different themes belonging to different viewpoints or to indirectly access to documents which may well be unreachable when considering only one viewpoint. They could also be used by a IR system in an automatic mode for elaborated thematic reasoning tasks [10]. To take benefit of the discovering and browsing properties of the NOMAD multimap model in an iconographic context we have mainly based our adaptation of the original model for the MicroNOMAD approach on a parallel implementation of a thematic mapping and of an image mapping on the same maps.

The basic principles of the multimap model along with these adaptations are presented in the next section.

3.2 Basic maps construction process

The MicroNOMAD basic image classification process is based on the Kohonen topographic map model [8]. This model considers that a data[1] classification can be viewed as a mapping on a 2D neuron grid in which neurons establish predefined neighborhood relation. After the classification process, each neuron of the map will then play the role of a data class representative. The main advantages of the Kohonen map model, as compared to other classification models, are its natural robustness and its very good illustrative power. Indeed, it has been successfully applied for several classification tasks [11] [12] [14] [17]. In our own case, each topographic map is initially built up by unsupervised competitive learning carried out on the whole iconographic database. This learning takes place through the profile vectors extracted from the image descriptions, which describe the characteristics of these images in the viewpoint[2] associated to the map.

For each neuron of a map *M*, the basic competitive learning function has the following global form:

$$W_n^{t+1} = W_n^t + \alpha(t)k(t)(W_{n*}^t - P_n^t)$$

<u>*where*</u>

W_n^t is the external weights profile vector (i.e. the class profile vector) of the neuron n at time t,
P_n^t is the description, considering the viewpoint associated to the map, of the image i chosen as learning sample at time t,
n is the winning neuron at time t, that is the neuron*

1. For our experiment, the data correspond obviously to the images of the database.
2. The "viewpoint" notion is an original notion that has been firstly introduced in the NOMAD IR system for playing the role of semantic context of retrieval [10]. In the framework of our image database specific viewpoints have been associated to each specific keywords set of the image description like "Indexer keywords" set, "Title keywords" set or "Author names" set. Other viewpoints could also have been associated to the visual characteristics of the images, if these latter had ever been computed.

which profile has the best match with the i image profile, a(t) a time decreasing function, k(t) a neighborhood adaptation function.

The topological properties associated with the Kohonen maps make it then possible to project the original images (i.e. data) onto a map so that their proximity on the map matches as closely as possible their proximity in the viewpoint associated to said map.

After the preliminary learning phase, each map is organized so as to be legible for the user through analysis of the main components of the neuron profiles.

A first phase of this analysis consists in defining class names that could optimally represent the class contents when the map is displayed to the user. Due to the fact that there is obviously no absolute strategy for achieving that goal (this problem is well known by automatic classification specialists as the "class naming problem") we choose to implement two different kinds of strategies that could be indifferently used during the map consultation phase:

- *The class profile driven strategies:* they consist of attributing to each class a name that represents the combination of the labels of the components having the maximum values in its profile.
  These strategies are well-suited in highlighting for the user the main themes described by the map.
- *The member profiles driven strategies:* they consist of attributing to each class a name that represent the combination of the labels of the components having the maximum values in either the profile of the most representative member of the class or the average member profile computed thanks to all the class member profiles. In this strategies, no name could obviously be attributed to intermediary classes due to the fact that they do not have any associated member.
  These strategies are useful in providing the user with complementary information for the map's themes content interpretation. Indeed, some important information on a theme could be better represented in the theme's member profiles, than in its related class profile[1].

The second phase of the analysis consist in dividing the map into coherent logical areas or neurons groups. Each area, which can be regarded as a macro-class of synthesis, yields a very reliable information on the relative importance of the different themes described by the map. Main themes are represented as larger areas (i.e. with more neurons) than the marginal themes. This "area effect" could also be considered as a very good illustration of the non linear mapping behavior inherent to the original Kohonen classification method. The area computation is based on the topographic properties of the neuron profiles of a Kohonen map [8]. These properties, that are only valid on a reliable map, guaranteeing both the continuity and the locality of the variations of the map neuron profiles, and indeed the closeness of the computed areas on the map. It has been presented in detail in [10]. The figure 3 represents a partial view of a resulting map in its finalized form. One can see that the "image mosaic" effect is obtained by "illustrating" the map thematic structure by the most representative image of each theme.

3.3 Intermap communication principles

3.3.1 General principles

The communication between Kohonen maps, that has been first introduced in the NOMAD IR model [9], represents a major amelioration of the basic Kohonen model. In MicroNOMAD, this communication is based on the use of the images that have been projected onto the maps as intermediaries neurons or activity transmitters between maps.

The communication process between maps could be divided in two successive steps: original activity setting on source maps (1) and activity transmission to target maps (2). The original activity could be directly set up by the user on the neuron or on the logical areas of a source map through decisions represented by different scalable modalities (full acceptance, moderated acceptance, moderated rejection, full rejection) directly associated to neurons activity levels [10]. This protocol could be interpreted as the users choices to highlight (positively or negatively) different themes representing his centers of interest relatively to the viewpoint associated to the source map. The original activity could also be indirectly set up by the projection of an users query on the neurons of a source map. The effect of this process will then be to highlight the themes that are more or less related to that query. Therefore, the activity of each map neuron is set up to the value of the cosine measure [15] between the neuron profile and the profile vector associated to the query. The activity transmission to target maps is based itself on two elementary steps: a first transmission step from the activated source map to its associated image neurons (down activation) and a second transmission steps from the activated image neurons to the target maps (up reactivation).

The activity A_i^T of a class i of a target map T derived from the activity of a source map S can be computed by the formula:

$$A_i^T = f_{n \in i}(g(A_n)),\ A_n = g(A_{j_n}^S)$$

<u>*where*</u>

n represents a neuron associated to a data, j_n its associated class on the source map,
f is a function implementing the semantic correlation computation described hereafter,
g is a bias function.

The activity transmission could be considered as a process of evaluation of the semantic correlations existing between themes of a source viewpoint (source map) and themes belonging to several other viewpoints (target maps). The figure 4 represents the result of such a evaluation on the iconographic database "Art Nouveau" considering three different viewpoints (maps).

3.3.2 Main computation parameters

"Possibilistic"[2] computation of the semantic correlation: in this approach each class inherited of the activity transmitted by its most activated associated data. The *f* function described above can be given as:

$$f = \underset{n \in i}{\mathrm{Max}}(A_n^-) + \underset{n \in i}{\mathrm{Max}}(A_n^+)$$

<u>*where*</u>

A_n^+ represents a positive activity value (positive choice), and A_n^- a negative activity value (negative choice).

This approach could help the user to detect weak semantic correlation (weak signals) existing between themes belonging to different viewpoints.

Probabilistic computation of the semantic correlation: in this approach each class inherited of the average activity transmitted by its associated data, either they are activated or not. The *f* function described above can be given as:

$$f = \frac{1}{\|i\|}\sum_{n \in i} A_n$$

<u>*where*</u>

$\|i\|$ represents the number of data associated to the class i.

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1. This phenomenon is due to the fact that the class profiles are drawn from the classification process while the member profiles represent a straightforward information from the original data.

2. "Possibilistic" is a neologism meaning that our measure is directly related to the measure of possibility defined by the possibility theory.

Conversely to the possibilistic computation, the probabilistic computation give a more reliable measure of the strength of the semantic correlations and may be then used to differentiate between strong and weak matching.

4. EXPERIMENTATION

4.1 Experimental context

We carried out a first experiment with the MicroNOMAD Discovering Tool on the iconographic database "Art Nouveau" managed by the BIBAN server. This database contains approximately 300 images related to the various artistic works of the Art Nouveau school. It covers several domains, such as architecture, painting and sculpture.

The images have associated bibliographic description containing optionally title, indexer keywords and author information. These description are managed by the DILIB workbench in XML format. We choose to use 3 different viewpoints (profiles) in our experiment:

- *The "Indexer keywords" viewpoint.* Its is represented by the keywords set used by the indexer in the keyword description field of the images.
- *The "Title keywords" viewpoint.* Its associated keywords set is build automatically through a basic keywords extraction (use of a stop word list and plural to singular conversion) of image titles. After the keywords extraction a new "Title keywords" field is added to the image description.
- *The "Authors" viewpoint.* It is represented by the set of authors cited in the image descriptions.

The first step of the experiment consists in transforming the image description associated to the chosen viewpoints in profiles vectors. For that step, we also choose to apply a classical Log-Normalization step [19] in order to reduce the influence of the most widespread words of the profiles. The second step is the original classifications building. Its has been implemented through the classical Kohonen SOMPACK algorithm [17]. The results, which consists in three different classifications associated to the three different viewpoints are then "dressed" and converted to XML format thanks to the DILIB tools. For the sake of portability, the core of the MicroNomad Discovering Tool has been developed as a Java application. Its entries are the XML classification files produced in the preceding step and it implements the class naming strategies, the maps division into logical areas, the map on-line generalization and the intermap communication process described above.

From a practical standpoint, the MicroNOMAD interface provides the user with several different querying and browsing capabilities:

- Browsing through the class of the maps in order to access to their main characteristics and to their associated images.
- Producing queries and afterwards reformulation with a classical querying interface, which nevertheless implements an interesting secondary effect consisting of the projection of the queries on the maps. Indeed, this latter effect could significantly help the user to evaluate the query consistency with respect to the database content: a focalized activity on the map will correspond to a thematically consistent query, a widespread or badly matched activity on the map will correspond to a thematically inconsistent query.
- Acting on the classes activities in different ways in order to highlight semantic correspondences between viewpoints, to find connotations of a query, to get complementary information on some images, or to retrieve images similar to the ones of a chosen class but being not indexed by the current viewpoint.
- Collecting image samples in a session memory for all kinds of future operations.
- Using peripheral tools, like variance and projection tools, for the evaluation of the quality of the classifications and for estimating the degree of influence of the different classes on the classifications.
- Activating links with the BIBAN server pages for highlighting the context of the different artistic works associated to the images.

The whole experimental context is synthetically described by the figure 2.

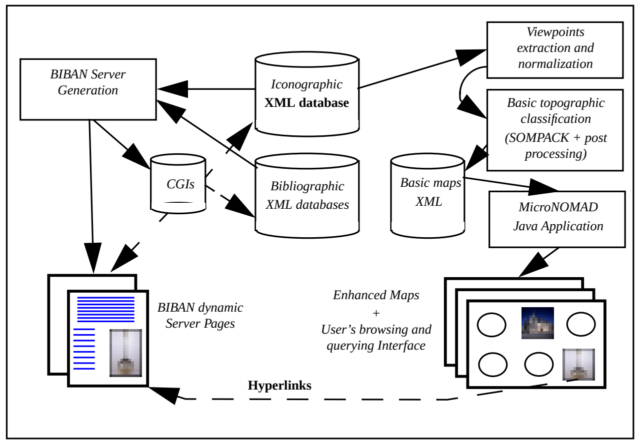

Figure 2: Experimental context

5. DISCUSSION

The first results which were obtained by our model are very promising. Original multiple viewpoints classification approach have directly produced very interesting results proving one more time the relevance of such an approach which tends to reduce the noise which is inevitably generated in an overall classification approach while increasing the flexibility and the granularity of the analyses[1]. In our experiment we found that a "Title keywords" classification can highlight information that is very complementary to the one highlighted by an "Indexer keywords" classification. For instance, in the context of the Art Nouveau database, we found interesting thematic extrapolation capabilities to the "Title keywords" classification, as well as complementary thematic focalization capabilities to the "Indexer keywords" classification. Indeed, crossings domain, like the common works of the Art Nouveau, are well highlighted by the "Title keywords" classification. As for it, "Indexer keywords" classification isolates very precisely the main artistic domains of the Art Nouveau while focusing on the most investigated sub-domains. Thus, the various naturalist metaphors integrated in the "Art Nouveau" works are very precisely described by this latter classification.

Maps also represent an useful tool for the indexation specialists. They help them in estimating the quality of the indexation of a database. Thanks to the classification method, strong indexation incoherences could be easily highlighted on the map: such incoherences are obvious if themes that specialists judged of equal weight in a domain appear with strongly different surface areas on a map. One example of such an incoherence that has been found by a specialist is the exaggerated representation of the Butterfly ("Papillon") theme, regarding to the Insect ("Insecte") theme, on the map of the figure 3.

After experimentation with several users, the opportunity to have simultaneously images and coherently organized textual information on the same support (map) seems to be definitely of great utility. Classification results interpretation are really made easier by the presence of images, as well as text represent a good

1. See [LAM 95] for another experimental and theoretical justification on that point.

help in the choice of reliable browsing points in the iconographic database. The model on-line generalization capabilities and its ability to derive the map description context in several ways could also significantly help the user in its database contents interpretation and browsing.

Thanks to the user opinion, the intermap communication process appears to be a very interesting and original feature of the model. It provides the system with a new capability that could be called a dynamic and flexible browsing behavior. Conversely to classical browsing mechanism, like hypertext links, the browsing effect could then be directly tied to the users information and explanation needs (see figure 4). Moreover, the number and the type (i.e. concurrent or complementary) of viewpoints that could be simultaneously used is not limited by the model. For example, one can easily add a new map representing a classification based on "visual indexes" extracted from the images. These last properties could led us to consider our approach as a good basis for building an intelligent multimedia discovering system that could be used for various discovering and analysis tasks, especially for the ones which are strongly tied to image interpretation. Indeed the model is now tested in two important applications:

- Interactive browsing through museum database and intelligent setting up of exhibitions in the framework of the technical collection of the french "Musée de la Villette".
- Management of multiple classifications of butterflies (colour, shape, ...) in the Taiwanese NSC Digital museum of butterflies [7].

6. CONCLUSION

The MicroNOMAD Discovering Tool development represents obviously a important step for providing an Iconographic interface to Digital Library Server with a high level of interactivity. We have said that the first reactions we received in demonstrating it in the BIBAN server context were very encouraging. Nevertheless, we have still a lot of work to do if we want to put such an interface on the Internet or to produce a tool allowing anyone to build this kind of application. The basic browsing and querying capabilities of our Tool seem to be well-suited for over-all browsing and querying tasks, whatever are the users abilities. Nevertheless, a real challenge comes from the relative difficulty for the non specialists of precisely analyzing the classification results that are produced by the Tool (and working on them). As shown in this paper, sophisticated tools give better hypothesis but they are more difficult to validate. Thus, in a «BIBAN like» context, we think that we will have to provide three different ways, depending of the user profile. People who just want to surf in a «tourist approach» will be more confident in a pre-computerized map which will give them a lot of paths to explore. On the opposite, specialists in classification models who want to investigate in a precise strategy could use a dynamic interface, closer to our present prototype. Another problem comes from domain specialists which want to get effective results by a deeper exploitation of both the expressive and the discovering power of the MicroNOMAD Tool but which are not familiar with neural theories and their background behavior: the MicroNOMAD multimap core model will be very useful to them in proposing new assumptions but we will have to connect him with very simple tools enabling non classification specialists to verify these assumptions. For that goal, we planned to interface our model with such a simple validation tool based on gallois lattice and dealing with logical inference [16]. In this way, our programing approach based on XML interfaced components will be very useful in declining various implementations from one model.

As the dimensions of the topographies processed by our system are not "à priori" limited, we are also planning to make use of rather strongly multidimensional topographies in order to represent much better some complex data relations[1]. In order to interpret this relations, the user will then be provided with multiple 2D projections of a same multidimensional topography.

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1. A straightforward example of such relation is a relation between several authors which is impossible to clearly describe on a 2D map.

8. APPENDIX : MAPS

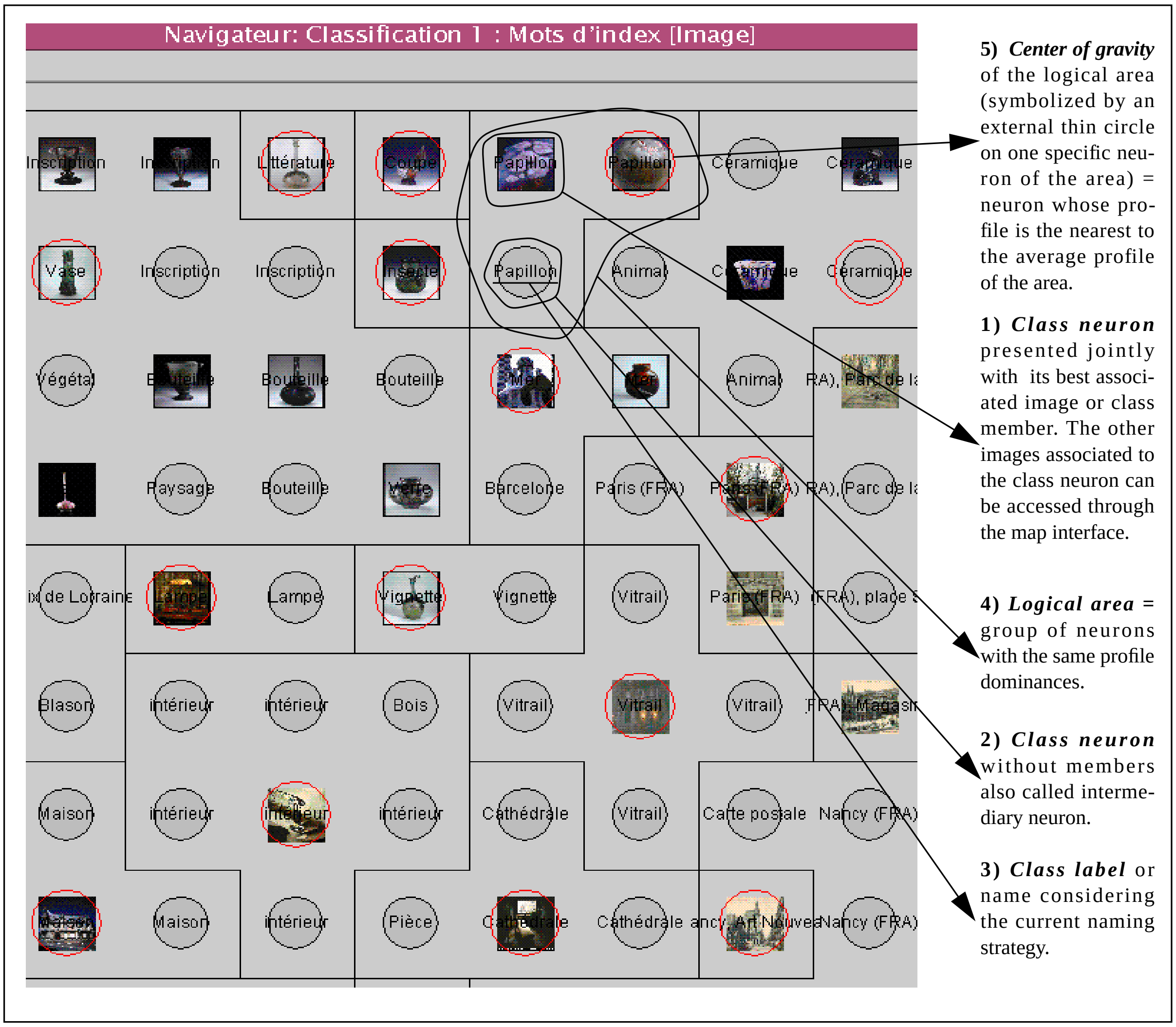

Figure 3: Map example

Partial view of a topographic map of 12 x 12 neurons (i.e. classes). The map is initially organized as a square 2D grid of neurons. The profile of the classes are then generated through an unsupervised competitive learning carried out on the profiles of 300 images of the BIBAN iconographic database considering one specific viewpoint. The viewpoint chosen for the showed map is the "Indexer keywords" viewpoint, with represents the bibliographic description of the images made by indexers (for more details, see Experimentation section).The names of the classes illustrate the themes (considering the chosen viewpoint) that have been highlighted by the learning. After the learning, the neurons related to the same themes have been grouped into coherent areas thanks to the topographic properties of the map. The number of neurons of each area can then be considered as a good indicator of the theme weight in the database. Considering, on the one hand, that themes or areas near one to another represent related notions and, on the other hand, that images, which represents the learning data, have been associated to their nearest classes on the map, the map could be considered both as a analysis tool and as a navigation mosaic with a semantically coherent organization.

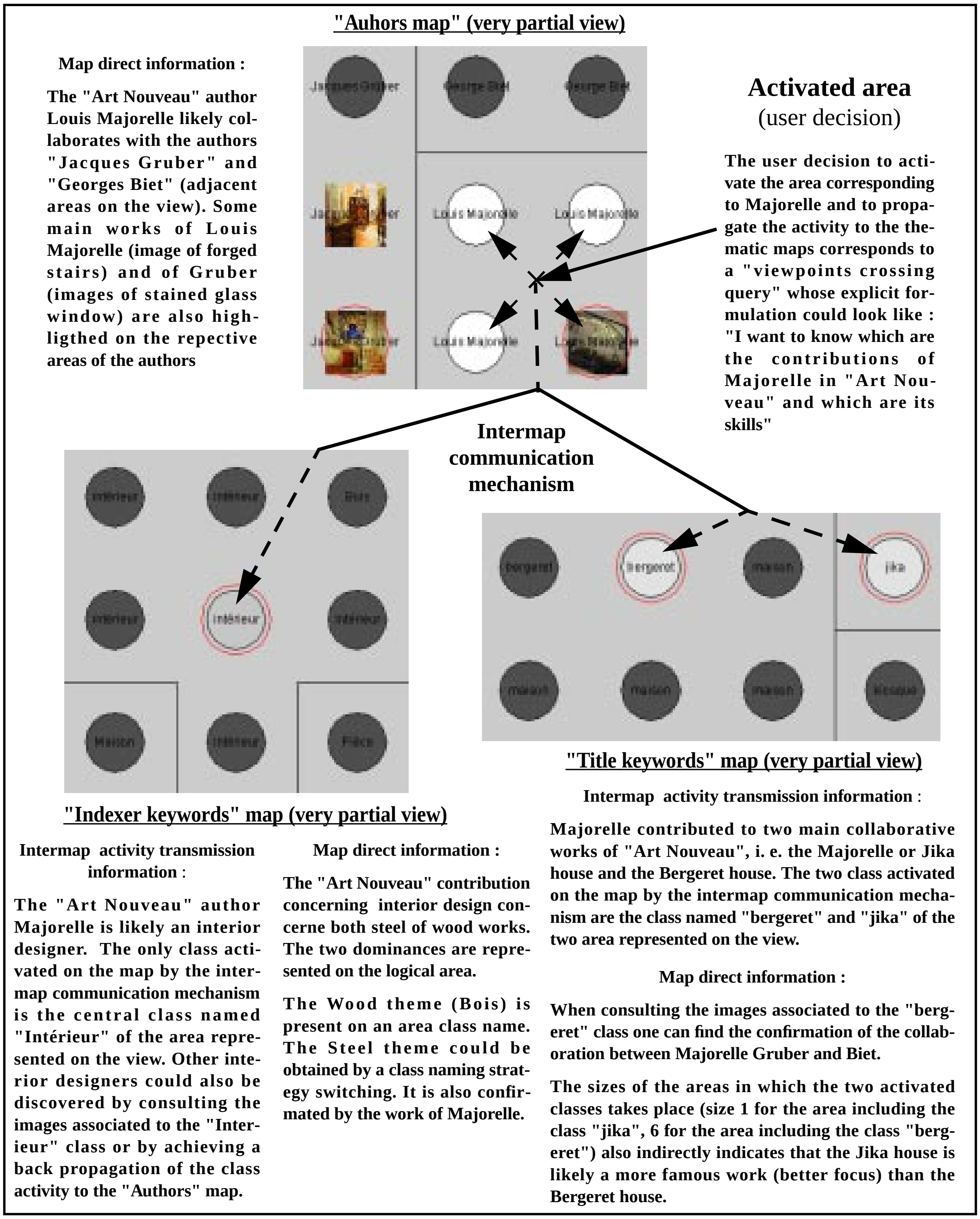

Figure 4: Intermap communication example

When navigating on a single map like an "Authors" map, the user can have a view of an author main works and of its main collaborations. When exploiting the communication between this "Authors" map and different thematic maps (here an "Indexer keywords" map and a "Title keywords" map) he can highlight the author various influence on the main thematic areas of the Art Nouveau, and moreover, its main artistic skills (see Experimentation section for more detailed descriptions of the "Author", "Indexer keywords" and "Title keywords" viewpoints).

On the figure, the maximum activity of a class correspond to white color of a its related neuron, the null activity to a dark grey color. For the sake of readability of these activities on the maps, the "Image display" mode has been switched off on the "Indexer keywords" map. and on the "Title keywords" map.