# THREE APPROACHES OF THE USE OF IMAGE TO ASSIST ARCHITECTURAL DESIGN

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**Abstract.** The image is the support of ideas search in the whole design phase. The definition of assistance tools, by using the image, seems to be applicable whatever the stage of the process of architectural design is. This article presents three approaches, which intend to study the contribution of the image inside of the architectural design process. The first approach rests on the idea that architects use external references as generating elements of new project ideas and that it is possible to organize this referential knowledge by taking the image as structuring entity of this knowledge. The two other approaches intend to use image to support the formulation of information designer's needs in more advanced phases of the design process. The identified needs are those of the architect who searches a particular information in order to justify or to perform some choices, during the act of conception.

## 1. Introduction

The image is, nowadays, a support largely used to carry information. The reasons of the efficiency of the image are well known and numerous. We are particularly interested in the following characteristics:

- Considerable physiological sensibility of the person whose perception is predominated by visual images,
- Great aptitude to memorization of images,

- Great capacity of information encoding,
- Instant global message,
- Prove effect,
- Iconic seduction.

In the activity of architectural design, the image, whether it is mental or physical, plays an important role in spatial reasoning. « A major source for extrinsic information of this sort consists of visual display that the designer intentionally or unintentionally scrutinizes. Visual displays have the advantage of containing information that already represents form and composition pictorially, as it's eventually required in the design process. Bringing additional and new pictorial information into the problem space has the potential of restructuring the problem representation. » (Goldschmidt, 1995).

According to the moments of design, the image can play different roles. We have identified three principal functions of the image:

- The reference image: in the early phases of the design, the image serves as an ideas search support. By copying or interpreting a physical image, the designer will construct mental images in relation with his project situation.
- The analogous image: the designer will search and identify possible solutions by making correspondence between the image of an object or a work and the imagined solution of a project,
- The model image: in the more advanced design phases, the image plays the role of a model of a conceived work. It will be used for the project communication.

The third function of image is today, notably supported by synthesised images or images of "augmented reality" - combining synthesised images and images of real objects or places. This function of the image reveals a specific problematic.

Within the framework of the research program "ConceptImage", we have privileged the two first functions by using the relevance photographic images for the "idea research" and "solution research".

## 1. "Kaleidoscope" a reference system for the architectural project

Among the diverse design strategies of an architectural project, our work intends to privilege a cognitive process, based on exterior elements that stimulate and aid the early phase of architectural design. We call these elements *references for the architectural project.* The references could be cases of architecture, of architectural types, or even a scent. These diverse elements represent the « open » aspects of the references — not being locked in a domain or a form of expression. The utilisation of references is based on a process of knowledge transfer; from a domain or a source

element, to another domain or a target element. There exists, however, a particular source of element, which interests us in a special way: the visual images. In the "Kaleidoscope" system, the image will be the principal source of "referential knowledge". Each user will organise his own "referential knowledge" in order to be able to use it in a design situation. Our objective is to create a tool to organise references and to facilitate the retrieval of references, which could serve as design stimulant elements. In order to specify the tool that assists an early architectural design phase, we have defined four *guide-ideas*.

## 1.1. THE FOUR GUIDE-IDEAS OF « KALEIDOSCOPE ».

### *1.1.1 Information, knowledge and interpretation.*

Information can be transform into a referential knowledge an *interpretation* useful in early design phase. We call "interpretation" the act of an architect who appropriates an image and gives it a signified. He transforms general information to a knowledge that is particular to him. A referential knowledge is constructed in time and from the designer's experience. This knowledge is organised into a semantic network, where nodes and links possess a meaning. In "Kaleidoscope" a reference is composed essentially of an image and concepts that are associated to image. The concepts will be the nodes of the reference database. A concept has to be extended as a "unit of content" (Eco, 1997, p.287), which brings a particular meaning to an image.

### *1.1.2. An open system of references*

We have named "Kaleidoscope" our open system of references to architectural project for two reasons: (i) because the referential base, covered by the system, represents knowledge in constant transformation and (ii) because this knowledge accepts non-architectural references. The analogical reasoning, that we want to favour, does not usually respect the limits or boundaries of a domain. Therefore, we proposed a system that complete the task accomplished by the Case Base Design (CBD) systems. In this way, *open* means that we open the possible domains of references.

### *1.1.3. Search and navigation*

During the reference definition process, two types of action will be constantly used: search and navigation. The notion of search means that an explicit objective to reach is known before the beginning of a search process. The idea of navigation includes the notion of exploration in which it does not exist a prior objective. The navigation, in a certain limit, is exploratory (Oxman, 1994 p.149). At the beginning of the architectural creation process, the

objectives are fuzzy, badly structured and in constant mutation, then the notions of navigation and discovery are quite appropriate.

### *1.1.4. Recovery and production of new knowledge*

The Kaleidoscope system proposes the concept of "creational book" (Grosselin, 1998). We imagine that during the search and navigation task, the user will be able to produce a new type of knowledge. A creational book represents a reorganisation of references according to a more precise objective, as, for example, a project that a user is currently creating.

## 1.2. EXPERIMENTATION AND PROTOTYPE

In order to realise experimentations based on our four guiding ideas, we have built a prototype called "Kaleidoscope". In "Kaleidoscope" a reference will be the result of the association of an I-reference, Concepts and a Narrative text (see figure 1). The concepts are organised in a particular structure that we have called a thesaurus of concepts, where they are represented by coded-images. A coded-image is necessary synthetic and economic in its representation. At the same time, the coded-image has to be clear enough to allow the associated concept to be recognised by the user. Each user will be able to construct his own thesaurus of concepts and modify it at times. The early version of "Kaleidoscope" possesses two ideas of thesaurus. The two thesauri — "Francis D.K. Ching" and "Dominique Raynaud" — have been constructed using the same method: we have transformed the two theoretical essays into two thesauri of architectural concepts, by starting at the hypothesis that we can interpret the non-architectural images by the means of architectural concepts (Scaletsky,2001).

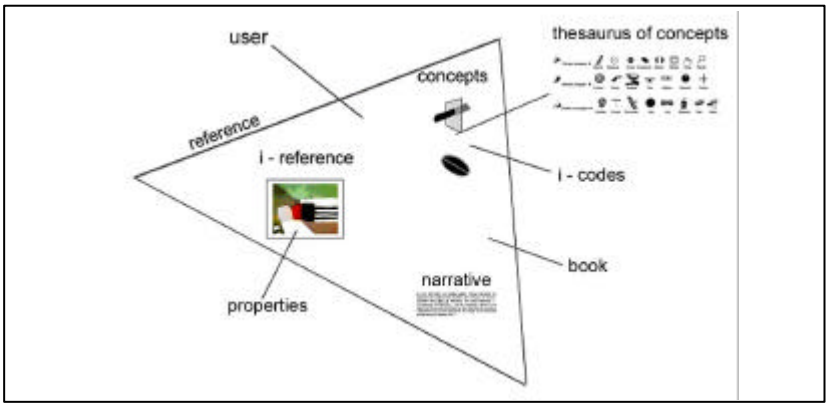


*Figure 1. Representation of a reference in "Kaleidoscope"*

The data interpretation is performed with elements that serve to interpret the image, and not with the image itself. An image can be interpreted from diverse points of view or concepts. We want to allow images to be interpreted in their variety, and not to be confined in a rigid and precise definition. The imprecision will be able to further the emergence of unexpected responses, which are considered as essential for a tool that claims to assist an early architectural design phase. In this semantic referential network, the concepts are nodes that possess a meaning.

The interpretation of an image reveals as well the association of a narrative and/or keywords (lexical *a posteriori*). We consider that there exists a complement between concepts and words in a way to interpret an image. According to Delage (1995, p66) « The use of words is an integral part and it facilitates this process ».

Finally, we propose a third way to organize the images by categories through the association of an I-reference to these properties (general and/or architectural — when the image belongs to the architectural domain).

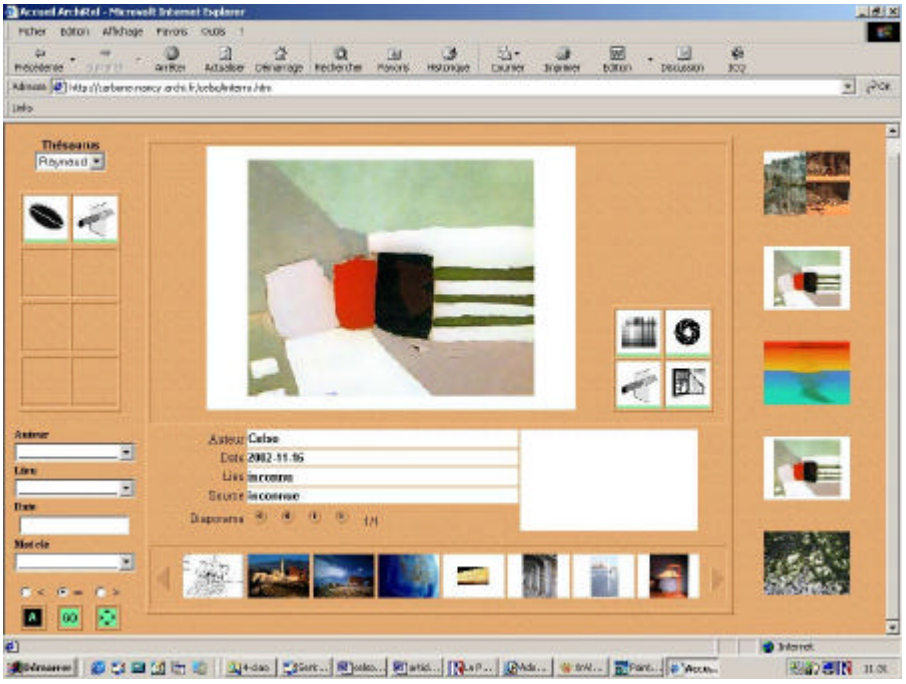


*Figure 2 – the "Kaleidoscope" system screen*

The method we used for the experimentation proposes a well defined task to experimental subjects. An experimental subject is always composed of two persons. We observe the produced attitudes and gestures (Grosjean,

1997). From these gestures and interactions with the system (see figure 2), we are able to better understand the reasoning made between experimental subjects. For example: the experimental subjects have to associate a suite of images (architectural or not) to architectural concepts present in the two available thesauri. We can already observe that the subjects can successfully associate architectural concepts with the non-architectural images, which is an important point to validate our idea of "an open system of references". But a more precise analysis seems necessary. The experimentation is currently in progress. A second experimentation is expected and we will try to observe the behaviour of the subjects in a design situation.

## 2. Search of constructive solutions by the image.

In this part, we present a different approach of the one proposed by the "Kaleidoscope" system. We propose to a designer, an assistance by the image applied to the search of constructive solutions. The objective consists in creating a database of referential-indexed images to assist the architects during their conceptual design. This database should allow:

- to help the designer using the so-called « technical » information supply, supported by the physical images, which are absents from their mental images (Denis, 1982),
- to illustrate the same architectural concept in many different ways,
- to suggest different architectural solutions to a particular problem, "the designer's problem".

### 2.1. THE USER'S NEED

The image corpus used for the realisation of this database concerns the domain of architecture and more specially the wood construction. The target users are architects. We have identified three principal types of need:

- The user is in a survey situation, he doesn't have preconceived ideas on what he searches and he finds out new solutions he doesn't know,
- The user has only a vague idea of what he is looking for. The designer searches for ideas, but he doesn't know what idea precisely,
- The user searches for a concrete element but he cannot put it in words. He knows exactly what he is looking for but he doesn't know how to formulate it exactly: for example the user searches for a roof-finishing element, but he doesn't know how to name it.

## 2.2. THE SYSTEM OF SEARCH BY IMAGE

In order to help the designer finding solutions to his design problem, an interactive and progressive search by the image (Nakapan, Halin, Bignon, Wagner and Humbert, 2000) has been developed by the Research Centre in Architecture and Engineering[1] (see § 3.4). Within the framework of this system, a first work consists in constructing the vocabulary, which will used to describe the illustrated architectural elements in images. This vocabulary will allow us to response to the user's need previously identified.

## 2.3. THE INDEXING VOCABULARY

Defining an indexing vocabulary is the result of an analysis of a sample of images similar to those we have to index. In order to efficiently answer to the user's expectation and to reduce the ambiguity resulting from the multi-interpretation of an image (polysemy), the created vocabulary has to formalise the language practices of the professionals, who have the same scientific and technical references.

The objective of this approach is not to propose to the user the unique and exact sample of an illustration, but rather to retrieve various and different illustrations where the user will be able to make his choice. The experience showed that in a search by the image system, the user does not want to obtain a single sample of image responding to his query. A certain quantity of the images is more adapted; it allows the user to precise his need by making selection and sorting (Dauzats, 1994).

### *2.3.1. Vocabulary construction*

The vocabulary created will have a double function. It will describe an architectural elements illustrated on the images and, at the same time, belong to a particular domain of architecture, which is one of the wood construction. The vocabulary consists of a structured list of controlled terms used as indexing terms of the image (Kattnig, 2002). The structure of the list has been defined to respond to each of the user's need previously identified, it is in three hierarchical levels (Reed 1999).

The categorisation of vocabulary terms starts with an intermediate level called "current level". It is organised in this way because numerous experiences have shown that categories of a specific domain are encoded in user's mind in the most characteristic form called prototype (Rosch, 1973). The definition of each of the level is then made with the use of rules of generalisation and specialisation (Aitchison and Gilbrichrist, 1987), (see figure 3):

[1] http://www.crai.archi.fr

- *The Current Level (CL)*
It represents the level from which the language is structured. This level is also called basic level because it contains the most important concepts of the language of the domain we want to describe. These concepts are those we learn at first. This level answers to the designer when he has a general problem. This level contains the name of concrete elements illustrated on the images (see Table 1).

- *The Superior Level (SL)*
It allows to response to the fuzzy and not precise demand. The system has to guide the user, during a search, towards a more precise and a more specific level. This level is more general than the basic level. It contains the term that allows to identify the common attributes of the architectural concepts belonging to the current level (see Table 1).

- *The Inferior Level (IL)*
The terms belonging to this level allow a more concrete identification of the architectural concepts illustrated on the images. It corresponds to a precise user's demand, where he searches for precise architectural solutions to his design problems. The terms belonging to this level are used to index the images. They contain only one degree of precision comparing to those of the current level. This specificity of terms is obtained by the search of the characteristics such as (see Table 1):

- The form: it corresponds to the set of contour of an object. This characteristic is visible in two levels (i) the form of the architectural element itself and (ii) the module used
- The constructive mechanism: it corresponds to the manner used to dispose or arrange the architectural element, according to the predetermined rules of construction,
- The functional mechanism: it mainly corresponds to the way the architectural element is used in order to fulfill its characteristic role,
- The number: it corresponds to the multiplicity or the uniqueness of a single architectural element,
- The orientation: it corresponds to the direction of the element relatives to the principal axes horizontals/verticals or intermediate axes,
- The solid-void mechanism: it corresponds to the piercing degree of the architectural element allowing the daylight to pass or not.

| **SL** | **CL** | | **IL** | |
|---|---|---|---|---|
| | **Term** | **Definitions** | **Characteristics** | **Term** |

| | | | | |
|---|---|---|---|---|
| Vertical structural system | Wall | Vertical structure shell | Constructive mechanism | Half-timbered wall |
| | Column | Vertical and punctual structure element | Formal mechanism of the element | Circular column |
| Outside facing | Cladding | Exterior front covering | Mechanism of the unit used | Shingle cladding |
| Outside shutting | Shutter | An outside moving panel for closing an opening in a wall. | Functional mechanism | Shutter flap |
| Structural system | Structure | The whole of integral element to stabilize a work | Number | Successive portico |
| Exterior closing | Solar shading device | Outside mechanism aiming to shield building from solar radiation | Direction | Horizontal louvers |
| Structural facilities | Partition | Non bearing wall | Solid-void mechanism | Honeycomb wall |

*Table 1.Example of terms in the three levels*

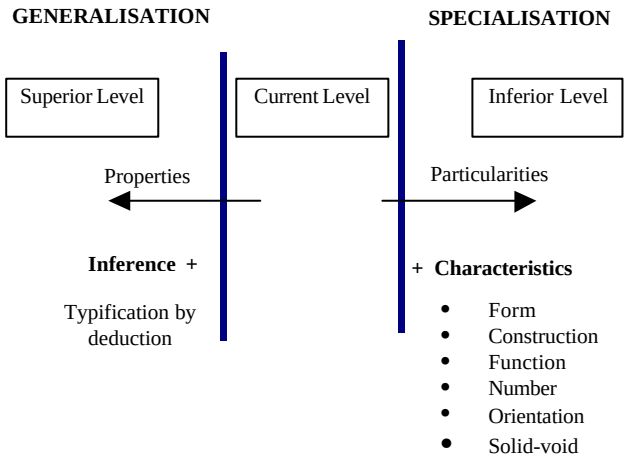


*Figure 3. The three levels of the language*

### 2.4. THE EXPERIMENTATION

In order to verify the pertinence of the formulated hypothesis, an experimentation is carried on. The experimentation is divided into two distinctive parts:

- The first part consists in validation of terms of the *current* or the *basic* level. In this part, the objective is to verify that the terms of the current level well correspond to the terms commonly used by the persons of the domain,
- The second part of the experimentation consists to verify that the three hierarchical levels answer to each of the designer's need when he is in design situation. This second part can be verified only after the validation of the list of terms (in the first experimentation).

Presently, the first part of the experimentation is in progress. The validation is done by the presentation of a series of images to subjects. These images illustrate concrete architectural elements that the user has to name. The objective of this stage is to verify that the name of the architectural object illustrated in the image, as given by the subject, corresponds to the one found on the list of terms in the current level.

The objective is to control the vocabulary in order to obtain a common description of images by avoiding an unnecessary specialisation of the vocabulary.

## 3. The product search by the image

The third approach in the use of image in the architectural design process is based on the investigation of the information in the more technical nature than in the two previous approaches. It concerns the information retrieval relating to building products.

### 3.1. THE PRODUCTS AND MATERIALS IN DESIGN

The use of the term “material” and “product” are quite ambiguous. The term “material” is often used in a general sense; it can mean either “material serving to construct”, or the “construction component”. In this last meaning, the term “product” can sometime substitute the term “material”. However, the qualification of product extends the notion of material. It associates at the same time, the commercial aspect (element possessing a trade value) and the industrial aspect, which is a result of a production process.

### 3.2. THE PRODUCT INFORMATION NEED DURING THE DESIGN PROCESS

Numerous authors assimilate the architectural design process to a problem formulation/resolution process (Grosselin, 1998), (Lebahar, 1997) and (Prost, 1995). The design process models based on this approach are structured in three phases that we can qualify in the following way:

- Initial (accumulation, diagnostic and definition of the problem),
- Intermediate (formulation of concept, search for the object, and exploration of solutions),
- Advanced (arranging, model construction, critic).

Even the advanced phase seems to be the most favourable concerning the product choice, many architects choose their product during the initial or intermediate phase of their design.

The identification of the type of user's need has been made by taking into account two factors:

- The level of precision: the need can be fuzzy, vague or precise,
- The capacity of expression: either the designer does not know how to describe his need with a precise vocabulary, or he knows exactly how to describe it.

From the two factors, three types of user's need have been identified:

(1) The user doesn't know exactly the product he is looking for and he doesn't know how to express his need,
(2) The user knows exactly the product he is looking for but he doesn't know exactly how to call it with a technical term,
(3) The user knows exactly the product he is looking for and he knows how to call it with a technical term.

The fourth possibility, i.e. the user doesn't know the product he is looking for and he knows how to call it with a technical term, is a type of user's need quite atypical, even impossible.

### 3.3. THE ONLINE BUILDING PRODUCT DATABASE

The support of technical information usually comes in forms of paper catalogue, cd-rom, or website. Among these supports, the online building product web-site that can be found on the Internet represents the most recent support, which has a rapid growth. The product databases represented on these websites, propose many kind of access mode:

- Free search,
- Multi-criteria search,
- Navigation by alphabetical order, by theme and by theme with the assistance of the image.

These three access modes have been conceived for the third type of the user's need that we have identified. In these search modes, the user has to type a text, or has to choose a textual criterion that best represents his need. Most of the time, the need is not precise even when the user knows exactly what he looks for, he doesn't always know how to express it in words. Only the navigation assisted by the image proposes an alternative approach (Batiweb[2], Batiproduit[3]). This access mode allows the user to rapidly identify the product by navigating progressively through a product classification represented by drawings and/or by images. The text is then in a second layer. This search mode can also response to the second type of user's need, but if the user cannot project his need (the first type of need), the search will fail.

### 3.4. THE SEARCH BY THE IMAGE

We propose a new access mode: the product search by the image. The principle of this access mode is shown in the following diagram (cf. figure 4):

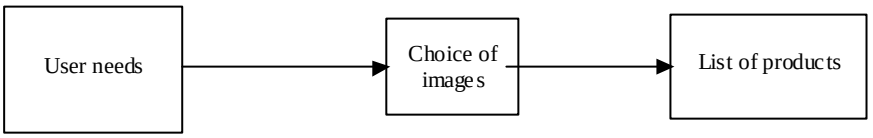


*Figure 4. The product search by the image*

The search by the image can response to all types of user's need. But it is for the first and the second type of need that we have proposed it. In both cases, either the user has problems of precision of his need, or he has trouble to express it.

Understanding the user's need is very important in technical information search. However, the system cannot give what the user finds acceptable if it does not ask what he thinks about the result (Eakins 1996). A dialogue between the user and the system can help to better understand the user's need. Consequently, an interactive and progressive image retrieval is proposed. This form of context-based image retrieval better uses the interactivity of the image (Halin & al. 1990). The technique of the "Relevance feedback" makes it possible for the system to understand the user's need more precisely.

[2] http://www.batiweb.fr
[3] http://www.batiproduits.com

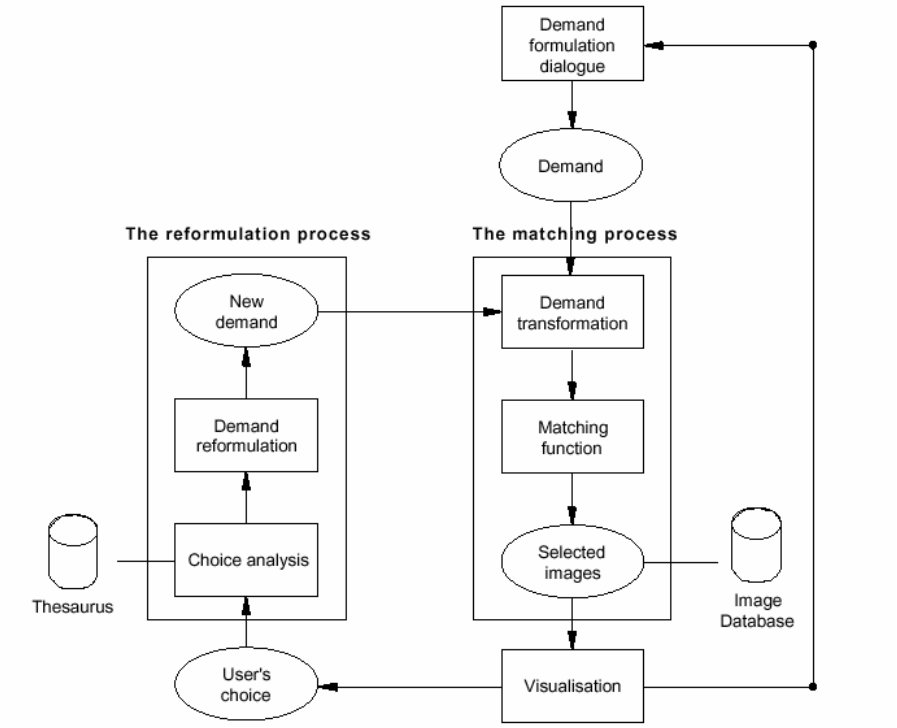


*Figure 5. The principle of the search process*

The principle of the search process (cf .Fig. 5) is as following:

- the user formulates a simple demand,
- the system analyses the demand and proposes a first set of images to the user,
- the user chooses or rejects images. He can also stay indifferent on an image,
- the system analyses these choices and reformulates a request in order to select new images that are proposed to the user.

The process stops when the user obtained a set of images, which he considers relevant. He can then see information on the products that the images represent.

### 3.5. THE CONSTRUCTION OF IMAGE DATABASE

In order to regularly collect the image, it is necessary to find a “source” that possesses four essential qualities as follow:

- Exhaustiveness: the source should potentially contain images illustrating all types of products in order to cover all type of user's need,
- Facility of acquisition: a manual acquisition of the image (via a scanner) is very time consuming. In order to reduce this cost, the acquisition should be completely automatic when dealing with a large quantity of images,
- Facility of indexing: once the images are collected, they should be indexed by a semantic indexing. However, a manual indexing is very consuming in time and human resource. Therefore, image indexing should also be automatic or semi-automatic. This type of indexing requires textual information for each image.
- Constant information update: the construction technologies evolve constantly. The architects look for new products as well as their pictures. The image source should be able to provide, regularly and nearly instantly, new images of the products, but also images of new products.

The Internet or the world-wide-web in particular, is at present the media that possesses all the properties presented above. Therefore, we have chosen it as a supplying source for our image database. The images coming from the web have already been used as information search support. Numerous search engines on the Internet propose an image search on the Web (Yahoo!, Altavista, Google, etc.). Moreover, the websites propose a diversity of subject. Among these websites, many of them are related to architecture, engineering, and construction. We wish to find many images of building product websites, especially ones illustrating products in our database.

A method with two phases has been proposed to realize the image extraction and the image indexation from the Web resource. We have described this method and the application in (Nakapan & al. 2000), (Bignon & al 2000).

### 3.6. EXPÉRIMENTATION

The DOCMAT product database has been chosen. This database references in total 5.503 products. We have selected 400 images that illustrate a part of these products. These images present the products indexed by the terms belonging to the two constructive functions: "roof" and "exterior opening". There are 1,172 products that have been indexed by terms belonging to these functions. Among these products, 101 products have been indexed by terms belonging to both functions. There are 1,172 products are therefore considered as potentially accessible.

In our context, the users in whom we are interested are exclusively the architects having architectural design problem relating to a particular project. This first evaluation has been performed on a sample of 21 architects. The result of this experimentation is summarised in the following table (see Table 2):

| | Users having finished the search | User's need type 1 | User's need type 2 |
|---|---|---|---|
| Number of user | 13 | 9 | 4 |
| Precision[4] | 0,52 | 0,56 | 0,35 |
| Number if stages | 4,1 | 4,5 | 3,25 |
| Satisfaction rate[5] | 68 % | 77 % | 50 % |

*Table 2: Summary of the experimentation result*

This first experimentation shows that this access mode covers very well the first type of user's need (77% of users satisfied, Precision at 0.56) with a number of stages of 4,5 on average. This number of stages allows the user to precise his needs. This result is very satisfactory, as this type of user's need isn't very much covered by the classic access mode found on the web. Considering the second type of user's need, this access mode rests satisfactory, it can complete the thematic search by the image when the user cannot project his need on the product classification proposed.

## 4. Conclusion

The experimentation conducted attests the interest of the image in many different activities that constitute the architectural design process. This relevance depends on the two principal qualities of the image:

- its analogical properties: an image makes it possible to establish a correspondence between what it represents and what exists or is projected,
- its holistic dimension: an image condenses a great quantity of information in an identifiable totality.

However, the image cannot avoid suffering from limits that can lead to information disorientation (the receptor does not know what he sees) or a semantic misinterpretation (the receiver interprets an iconic information

[4] $\text{Precision} = \frac{\text{Number of relevant products retrieved}}{\text{Number of all relevants products according to the query}}$

[5] $\text{Satisfactory rate} = \frac{\text{Number of users who have found products he searches for on the proposed list}}{\text{Number of all users who have finished the search}}$

differently that what the transmitter wants). To solve these problems, we are working on two directions nowadays:

- Better identify the relevance criteria of the image for an indirect function,
- Associate textual concepts to the images in order to better guide the user's interpretation.

These directions are those currently followed in the projects presented here.

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