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Image indexing vocabulary in architecture
Taxonomic hierarchy and categorisation

Sabrina KACHER[1], Jean-Claude BIGNON[2]. Gilles HALIN[3]

Summary: Architectural design is a domain where the use of pictures (drawing, photography,…) is essential, because the information transmitted by photographic images are often more easily to understand than the one transmitted by texts. This paper presents a common vocabulary and its structure relations used for professional people belonging to the wood construction domain researching information for their project through images. The images allow us to transmit necessary and lacked information, to the designer, by illustrating " reference objects " in their absence. To help the designer, we propose an image database illustrating existing architectural constructions. The problem we are faced with is the filing and the classification of those images from a semantic point of view. This classification cannot be done without identifying the information transmitted by images and their transcription in a structured vocabulary. The structured vocabulary includes the name of the illustrated architectural objects to facilitate access to the information during research. The question is " how to describe at the same time visual and recognisable architectural elements in words?".

Keywords: content-based image retrieval, ontology relationship, logical relationship, categorisation, classification.

1 Introduction:

Image is widely used as an information support in the design field because it can convey a great number of information that will help the designer to solve his design problem in a minimum of time. Several researches shows that image bring two kind of information features, the first one concerns its graphic content such as colour, shape, texture (Del Bimbo 1999) and the other one concerns its semantic content relative to the interpretation of the representing elements appearing on the images.

The following work is situated within the frame of the general problematic of assistance to the architectural design field by images. More precisely, we try to help the designer when he looks for constructive solutions to his design problem. By constructive solutions, we mean, buildings or parts of buildings (houses, windows, etc) but also engineering works or parts of those works (bridges, footbridges, etc). The following paper defines fundamental notions and semantic relationships, which are necessary to create an adapted language for describing architectural elements illustrated by images. To help the designer find solutions to his creation problem, an

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interactive and progressive research system by image [BHN 00] was developed by the CRAI[4]. Within the framework of this research, our work consists of defining the vocabulary which describes architectural elements illustrated in the database This defined vocabulary will be inserted to the system developed by the CRAI aimed to answer the user's needs identified as follows.

2 The user's needs:

The target users belongs to the architectural domain, such as architects, designers… We identify three types of user's needs, which can be answered by developing a system of information retrieval by images :

- The user is in a watching brief situation. He doesn't have any preconceived ideas of what he is looking for. He only wants to be informed of new solutions available by visualising images.
- The user has only a vague idea of what he is looking for. He searches for ideas but he doesn't know what precisely. He visualises images and then, during his navigation, starts to progress in solving his design problem.
- The user is searching for a concrete element. He knows exactly what he is looking for but he can't formulate it exactly: for example the user searches for a roof-finishing element, but he doesn't know how to name it.
- The designer can express clearly his need and he only wants to see examples illustrated on the image database.

To answer the designer's needs, using the image, we propose help applied to search constructive solutions. The objective consists of the creation of an indexed image database to assist architects in their design work. This database aims at:

· Helping the designer with the so-called « technical » information transmitted by the physical images, which are absent from his mental images [DEN 82].
· Illustrating the same architectural concept in many different ways.
· Suggesting different architectural solutions to a particular problem, "the designer's problem".

3. Image describers

The database contains photos which belong to the corpus of the architecture and the wood construction domain. To be interpretable, these images are indexed according to a model of family describers, Figure (1) :

The first family of describers are called " OFFNESS ". It is an approach related to the extractive information from the picture. We identify:

· The graphic content ; concerns everything directly legible on the picture (colour, texture, shape,…)
· The semantic content ; concerns the identification elements represented and legible directly on the picture:

The other family of describers are the so-called "ABOUTNESS". It is an approach that carries on the complementary or the interpretative but no directly extractive information from the picture. We identify:

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· The contextual content ; is related to concepts no legible directly but having a obvious connection with the content of the picture (type of project, name of project, geographical situation,…)
· The symbolic content is located on a more elevated abstraction level which is the semantic level (opacity, permeability, monotony,...)
The following diagram allow us to summarise the different families of describers below, the part in dotted lines represents our context of work. Consequently, we propose a model including concepts directly related to the architectural project (contextual and semantic content).

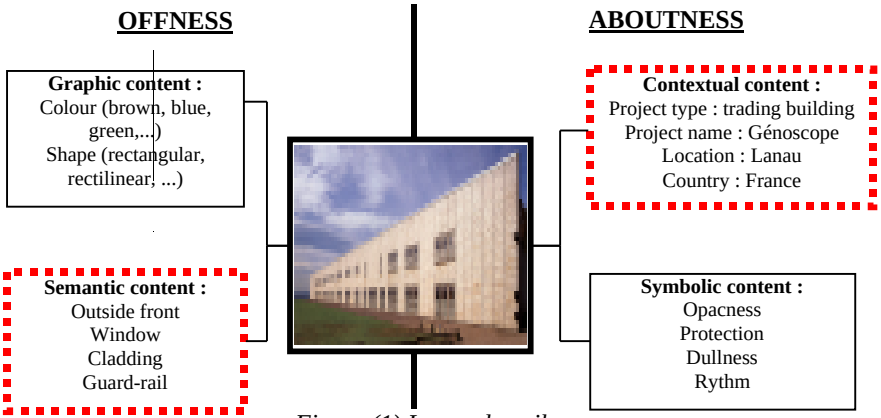


Figure (1) Image describers

4. The proposed language:
This work is based on a database containing about 1000 images. It is important to clarify that for more efficiency, the corpus of selected images illustrates architectural works belonging to a particular domain of architecture which is the wood construction field. This limitation allowed us to add another dimension to the description language which is the type of the "material used".
This language [HUD 94] must be completely without any ambiguity [AG 87] and will have to resume in its structure the common constructive principles of the professional people in the domain for which the vocabulary is established [DAU 94]. This classification cannot be made without the analysis and the identification of the information transmitted by the images [KAT 02]. Indeed, an image is perceived clearly only if the receiver can distinguish construction elements (roof, window) to which he can attach a name [MOL 71]. This situation leads to implement an structured indexing vocabulary, resulting from the transcription of the information conveyed by the images to facilitate access during research. The vocabulary is divided into 4 classes:
· The constructive functions ; indicates every part of a whole architectural work which has an essential or a particular function.
· The material; includes every wood material and its by-products (species, glued-laminated)

- The products; include any component aimed at protecting and to decorating wooden elements (fungicide, impregnation).
- The type of building; includes the name of the category to which the work element illustrated belongs (school, single-family dwelling).

According to the user's needs identified before, we suggest structuring each class in 3 hierarchical levels [REE 99] :

4.1 The current level "CL":

It represents the level from which the language is structured. It contains the name of the concrete elements illustrated by images. This level is also called the "basic level" because it includes the name of the most important architectural concepts in the language in the domain. It also includes terms we learn at first. It orients the designer when he looks for a general architectural work, because it includes the name of the "prototype" [ROS 73] or the most representative member of elements having common characters.

4.2 The superior level "SL":

It answers to the designer when he has a vague need. This level represents a more general level than the "current level". It includes terms which anable the naming of the attributes shared by architectural concepts belonging to the current level, *table (1)*. It allows the user, during a research, to cross from a general level to a more specific one.

Table (1)

SL	CL	
	Terms	Definitions
Vertical structural system	wall	Vertical structure shell
	Post	Vertical and punctual structure element

4.3 The inferior level "IL" :

This level permit a more concrete identification of the architectural concepts illustrated by images, than the previous levels. The concrete expression corresponds to the user's need when he looks for precise and specific architectural solutions to his design problem. Terms belonging to this level are used for indexing images and include only one further degree of specificity than those belonging to the current level. This specificity of the terms is performed by researching characteristics such as *:*

4.3.1 The shape;

Corresponds to the "contour" of an object. This characteristic has two levels. i) the shape of the architectural element itself eg : Post → Circular post and ii) the unit used eg : indoors flooring → pannels.

4.3.2 The constructive mechanism;
Corresponds to the way the architectural element is arranged, according to predetermined rules of construction. Eg : Wall→ Half-timbered wall

4.3.3 The functional mechanism;
Corresponds to the way that the architectural element is used to fulfil its characteristic role. Eg : Cladding → Shingle cladding

4.3.4 The number;
Corresponds to the multiplicity or to the uniqueness of a single architectural element. Eg : Structure → Successive portico

4.3.5 The orientation;
Corresponds to the direction of the element with regard to the horizontal / vertical or intermediate axes. Eg : Sun-breaker → Horizontal louvers

4.3.6 The full-empty device;
Corresponds to the extent to which the architectural element has been opened up with the aim of letting in daylight or not. Eg : Partition → Honeycomb wall.

5 The hierarchical relationship in the language:

The lexicon terms must be unambiguous. Which means that every term of the lexicon represents only one single concrete element of the image [CR 01]. This unambiguous side cannot be reached without control of the language. Following the example of the wood construction domain in which every element is connected to the others and constitutes a complete architectural work, the constructed vocabulary includes terms which are related to the others in that same specialised domain, which constitutes a notional field representative of that field of knowledge. Several research works have shown that the various concepts which are a part of the same notional field are connected by two types of relationship: the logical relationship and the ontological relationship [CAB 99].

5.1 The logical relationship:

This kind of relationship is based essentially on the similarity between two concepts. Two kinds of relationship result from the comparison between various concepts, *figure (1)* ;

5.1.1 Generic to specific;
The first type of relationship concerns the case the "generic" concept transmits its characteristics to the "specific" one but the reverse is not the case. The specific concept, more than the characteristics transmitted by the "generic", possesses its own particularities. This type of relationship is called "logical hyponymy". Ex : partition → partition cupboard

5.1.2 Specific to specific;
The second type of relation concerns the case where two notions are specifics from a same generic notion. That means, two concepts share characters of the generic

concept, but each of them possesses its particular characters. This type of relationship is called "the logical coordination". Ex : mast, pilotis → post.

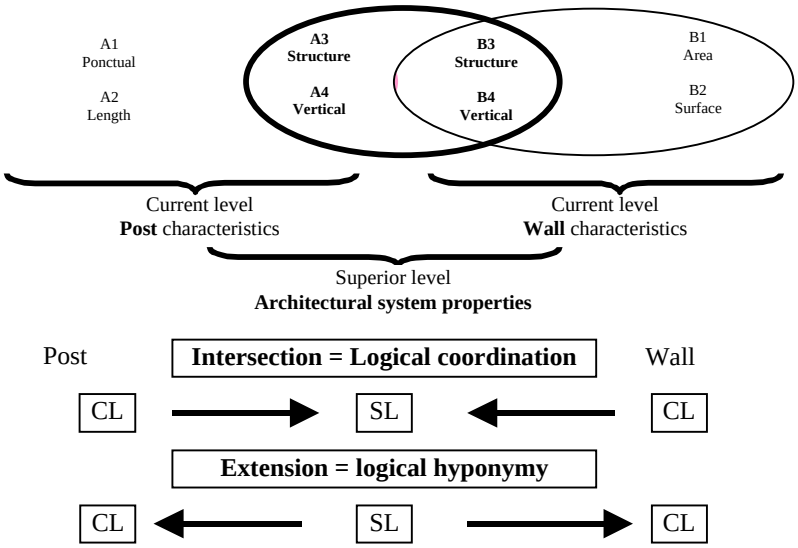


Figure (1) *generalisation / specialisation*

The combination of these two types of notions (generic→specific and specific→specific) define a hierarchical field of concepts. It consists of a vertical series of notions which maintain normally an inclusion relationship.

5.2 The ontological relationship:

This type of relationship isn't based on the comparison between two concepts as is the logical one, but concerns their situation in the reality. Ontology [NF McG 01] is the study of objects, the way they are ordered in reality and the relationship between them. It's also a model of the reality of the described domain, and the concepts belonging to an ontology must reflect this reality. So, those relationships between terms are "diagonal" unlike the logical relationship. We distinguish two types of ontological relationship.

5.2.1 Coordination relationship;

(part-whole) contains two types of relationship; those existing between a whole and its parts (house- structure, roof, windows..) and those existing between the various parts of the whole (structure, roof,...). These relationship are based on the space relatedness of the objects and occur consequently simultaneously.

5.2.2 Chain relationship;

Is based on successive events through time (cause-effect relationship) and are consequently sequential. Various studies have shown four distinctive criteria for

“meronymy”:

- Functional; appears when the part has a particular function relative to the whole. So a “rail” is a functional part of a "sliding door".
- Homeomer; appears when the parts are materially similar to the whole (and each other). So a "post" is a part of "colonnade".
- Separable; appear when part can be separated from the whole. So a "house" without "roof" remains a house.
- Simultaneous; appear when parts are presented at the same time in the whole. So the "roofing" is a simultaneous part of "roof".

These various characters could be combined in various types of relationships:

- Component / object ➔ framework / roof
- Member / collection ➔ fir tree / species
- Portion / mass ➔ post / colonnade
- Material / object ➔ glued laminated / framework
- Place / region ➔ head of post / post
- Phase / process ➔ structure / house
- Characteristics / events ➔ stand / building exhibition

5.2.3 Inclusion relationship;

The ontological relationship "part-whole" also allows the inclusion notion to be clarified which is a " non-transitive extensional " logic. That simply means the decisive fact that the notion which includes an entity, possesses attributes which are different from those characterising the entity included. Ex nose / face or opening / partition.

6. The experiment:

To evaluate the relevance of the formulated hypotheses, an experiment is carried out to validate the completed work. It divides in two different parts:

- The first one consists of validating the terms of the current level. In this part, the objective is to check that the terms of the current level correspond to the common use made of it by the professional belonging to the domain.
- The second part of the experiment consists of verifying that the three hierarchical levels of the vocabulary answer each identified designer’s needs. This second part can be verified only after the validation of the list of terms (first experiment).

So far, the first part of the experiment has been done with people specialised in the wood construction domain. The objective is to succeed in producing a common description of the image, avoiding too great a specialisation of the vocabulary.

6.1 The subjects selected for the experiment ;

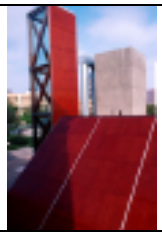
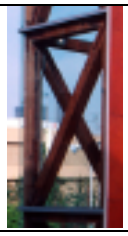
The specialised subjects who participated to this experiment are divided in two parts: engineers and architects specialised in the wood construction domain. The validation is made by presenting to the subjects a series of images illustrating concrete architectural elements, for which they have to give a name.

6.2 The images for the experiment ;

Every image belonging to the database was studied. Those selected were done so

according to the element considered as illustrating the most representative element of the category "the prototype". The purpose of this re-centering is to avoid various interpretations of the image because the particularity of the prototype is to evoke immediately the element to the subjects. For that, Every image was re-centered to illustrate only a single element in particular *Table (3).*

Table (3)

Raw image	**Image proposed to the experiment**
	

To decrease the over-precision that this type of re-centering could evoke, the idea was to propose not one but two images. Each image can be described by two different "specific terms" belonging to the same category of the curent level *table (4).* For that, the second image was added in order to have no terms belonging to the inferior level but only those belonging to the current level.

Table (4)

(specific level)	**(current level)**	**(specific level)**
Image (1)  Glass roof	**Roof opening**	Image (2)  Roof window

6.3 The protocol

The experiment was performed in several stages:

- Stage (1) presents a series of images in pairs to the subjects. Every pair of images is identified by a number
- Stage (2) asks every subject questioned to name the architectural work which describes each image in the pair.
- Stage (3) estimate the obtained results. This stage is divided into two parts :

- Verify that architectural elements in the images have been correctly described and the illustrated elements recognised (to validate the definitions).
- Compare the terms chosen by the users to name elements illustrated with those present in the current level of the defined vocabulary.

6.4 The results

The first part of the experiment showed that the people questioned, architects or engineers, possess a common vocabulary when we are situated at the common level of the language. We obtained about 70 % of recognition and answers corresponding to the present terms in our vocabulary. However the engineers add a little more technical dimension which is the used product of wood. For example they do not just say "beam" but " glued laminated beam". They also do not only say "post" but "class 4 post". This means that this type of information is present in their ordinary language and they are able to identify it in images.

Furthermore, this experiment allows us to determine, through the predefined relationship in the previous parts of the article, the ambiguities made by the subjects when they interpret a concept. For example for people questioned, it's very difficult to distinguish between a beam and a joist. This occurs because people tend to categorise architectural elements according to their performance. They confuse them because they have a similar functional role and also similar shapes. This means that elements which have the same shape and work in the same way tend to be categorised in the same family, while, in our vocabulary, beams belong to a different semantic field from that of joists. The problem is that with our vocabulary, this kind of ambiguity does not exist because the relationships established are made according to the existing precise definitions. So we have to define a new kind of relationship that corresponds to this sort of confusion.

7. Conclusion:

In this paper we have shown a way to describe images according to what can be recognise and reached by a designer to better formulate his design problem to advance in its resolution. The proposed vocabulary is structured in three hierarchical levels related to each designer needs. We have presented relationships to structure the lexicon representing the knowledge of the wood architectural domain. Experimentation also allows us to define convenient relationships to anticipate the user's needs and reactions. After validating the vocabulary, an indexing model will be established to put in correspondence images with the illustrated concepts. A second experiment will be finalised to verify that the image brings a significant help to the designer when he is in a design situation.

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