602: Integrating the perceptual dimension into decision support tools related to the environmental quality of materials.

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Abstract

Architects specialising in environmental architecture use, conceive, develop and upgrade, many tools to help the design process. Today, many of these tools are software based and related mainly to physical data: thermal, light, ventilation, acoustic, energy, ...

Our work concerns how sensible characteristics are incorporated in these design tools. We focus particularly on the choice of materials and the processes of their implementation.

We start from epistemological concepts to characterise the design process. Then, we examine various existing designs tools from the environmental engineering world: Dial-Europe (natural light), Audience (solar energy), Delta-P (tropical natural ventilation), Pleiade+Comfie (energy simplified transient state). We look at how sensible characteristics are presented in the design tool interface and how these effects integrate with the other physical characteristics. We deduce various guidelines for the interface and functionality of the design tools to help the designers as effectively as possible.

Finally, we synthesise a bibliographical study of the sensible characteristics of materials in architectural and urban design. We are particularly interested in the aesthetic effects of the materiality as well as the relationship between the volumetric effects and spatiality according to the implementation process. We deduce different aesthetic expectations of the designers.

We conclude by detailing the points that need to be developed to improve the operational character of the design tools in the choice of materials. These points allow a satisfactory compromise between the design choice and the environmental quality and architectural quality of projects.

Keywords: design process, materials, perceptual dimension, aesthetic.

1. Introduction

In the building area, questioning is constant in all project phases (from diagnosis through project development to construction of the edifice, its use and even its dismantling). As a result, this questioning is present at all levels: impact on urban planning, landscape and architecture through to the choice of all construction materials. Within this overall approach, we focus on the choice of materials in the initial project phases.

This choice is characterized by a "physical approach" which is developed with the aid of computer-aided design software by comparisons of performance (thermal, acoustic, air quality, daylight quality, etc.), varying the construction systems, choice of materials and their use (internal/external insulation), thickness, etc.

However, this choice is not made solely by a comparison of figures. In addition to their intrinsic performance characteristics, these materials develop the expressive force of facades. They give sense, use connotations, aesthetic expressions and so on, which develop the image of the project, so dear to our societies. This choice must enhance and highlight the architectural and urban expressions of projects which develop environmental ethics. But how can we help designers to integrate the perceptual dimension in the choice of materials from the very first phases of a project in a context of environmental reflection?

2. Method

The key theme of our work concerns the integration of qualitative criteria for materials from the very first project phases within a design support tool. It leads us to formulate the question "How can we characterize the perceptual dimension of materials?".

To answer this question, we have broken down our work into four consecutive sections.

The first section studies modelling of the design process. Our aim is to take account of designers' operating processes, in order to develop a tool that is in consistent with their practices.

The second section covers existing design support tools in the engineering field. After a summary presentation of these tools, we analyze how they are integrated into the design process and how the perceptual dimension and the physical dimension are processed.

The aim of this analysis is to pave the way for developing an interface concerning the perceptual dimension of materials.

The third section defines the perceptual dimension of materials. It is supported by a bibliographical study of the perceptual dimension, and is aimed at reaching an understanding of how information on the perceptual dimension of materials can be communicated.

Lastly, we have all the elements we need to produce a summary of all the notions previously covered in a fourth section. We propose an interface for a design tool focused on the perceptual dimension of materials.

To conclude, we define different paths to be developed with the aim of improving the operational nature of design decision support tools for materials. These paths aim to reach a satisfactory compromise in the design process, to ensure both the environmental quality and the architectural quality of projects.

3. Design processes

To meet the aim of our project, we must study the operating processes of future users, which raises the question of integrating our tool into designers' practices.

Our tool is intended for use in the initial phases of designing on a project. This phase is characterized by its "imprecise precision" approach, as defined by Lebahar [2]. We use cognitive approaches in the field of design to identify procedures [3].

The study of these different mechanisms has led knowledge engineers to distinguish four forms of reasoning: inferential activity, judgement activities, reasoning by analogy and diagnostic activities. These notions are defined by Fernandez [4]:

- Inferential activity: the human subject has the capacity to develop, from primitive information on the state of his or her environment, other information on this environment that is completely internalized.

- Judgement activities: the processes of judgement in evaluation, based on the principle that preferences are expressed on a set of options.

- Reasoning by analogy: this takes place when there is a relationship of similarity between two elements. Reasoning by analogy leads from a known resemblance between two things to an as yet unknown resemblance. It is a matter of drawing new conclusions on the basis of resemblances between two things

- Diagnostic activities: Rasmussen [5] suggests viewing diagnosis, when it is fully deployed, as a chain of activities leading to detection (abnormal condition, explicit search for information, identification of the state of the system, interpretation of consequences), action (choice of an aim to be achieved, breakdown of this aim, establishment of a procedure, execution of the procedure). However, as suggested by Bainbridge [6] this model is too linear and needs to be made more complex by introducing feedback loops (making it possible to identify errors in the process of the activity itself) and allowing anticipation.

4. Design tools

We have chosen to analyze the operation of four interfaces of design applications used in the field of environmental engineering. Our objective is two-fold: firstly to analyze how these applications adapt to the initial phases of the design process, and secondly to understand how the perceptual dimension is transmitted in the interface of these tools and how it interacts with the physical dimension.

4.1. Presentation of the tools studied

We have deliberately chosen tools produced by different laboratories, in different parts of the world and at different times, and above all concerning different environmental themes:

Dial Europe [7], an application used to predict the availability of natural light in indoor spaces. It was designed within the framework of a European project, as an extension of a doctoral thesis produced in the Architecture Department of the Lausanne Ecole Polytechnique Fédérale by Paule [8].

Audience [9] is a European remote self-training project, designed for architects in the domain of ambience control. The objectives of Audience training are to provide information on questions related to sunlight.

Pleiade + Comfie [10] is an application for calculation by dynamic simulation of multi-zone thermal exchanges in buildings. The COMFIE calculation module was developed by the Energy Centre of the Paris École des Mines ARMINES (Peuportier and Blanc-Sommeureux)

Delta T is the first of a generation of tools providing information on the potential for natural ventilation of the tropical habitat induced by urban forms. It was designed within the framework of a doctoral thesis at the University of Nantes, produced in the CERMA laboratory (UMR CNRS 1563) by Bonneaud [11].

Our aim is not to assess the performance of each software application. Our analysis is therefore solely oriented towards results (the essence of reflection).

4.2 Integration into design process modelling

Based on the four forms of reasoning listed above, we can examine how these applications produce input to and enhance the upstream phases of the design process.

Adaptation to "imprecise precision": data entry enables the designer to define a project approximately. For example, for the calculation of light reflection, the designer chooses a wall that is very light, light, dark or very dark. He therefore does not need to define exactly the type of wall covering required, but just to state the idea of the effect.

Judgement and diagnosis activities: applications in which data entry produces a 3D image of the project concerned, give the designer the ability to consider, analyze and diagnose the morphology of the project.

Reasoning by analogy: software applications illustrate their proposals by providing references. We make a distinction between references that

are calculated by the software, enabling designers to compare their solutions with examples, which we refer to as "comparative references", and references that are analyzed architecturally and transmit knowledge and skills to the designers, which we call "analyzed references".

4.3 Relationship between the perceptual dimension and the physical dimension

The physical dimension is generally based on the current standards for quantitative evaluation of the project.

The perceptual dimension is generally defined by the perception of the senses. According to Crunelle [12], perception is 98% visual. However acoustic, olfactory and tactile perception must not be neglected in architecture, town planning and landscaping. These are the senses that make users receptive to architectural, urban and landscape ambiences.

The software applications studied mainly deal with indoor climate and comfort in terms of heat, sound, light, ventilation, etc. It is precisely at this point - between comfort (which can be quantified) and indoor climate (which can be qualified) - that the relationship between the perceptual dimension and the physical dimension comes into play.

An analysis of the applications studied shows us that there are two categories. The first (Pleiade + Comfie) forms an "additional" system.

The perceptual dimension is created by entry of the 3D image, while the physical dimension is only present for the user in the final phase for performing the calculations. We note that the "additional" system gives rise to a free-form navigation mode.

The second family (Audience, Dial Europe, Delta T) form a "fusional" system in which the physical dimension is masked by the perceptual approach. To achieve this result, the interfaces develop a linear path. However, the navigation mode can be a directed linear path (Dial Europe) or a free linear path (Audience) in which users choose their entry point.

As these interfaces are designed for the initial project phases, they have a simplified appearance for designers, who "discover" or "question" their projects gradually as they use these tools.

5. The perceptual dimension of materials

Concerning materials, as demonstrated by Fernandez in "Environmental quality of materials: software tools pertaining to architectural quality"[13], there are numerous databases accumulating all the technical data. Secondly, there are databases of buildings that can be sorted by type of materials (Archinform, Mimoa, etc.). In both cases, these are descriptive bases in which the perceptual dimension is only represented by photos (without materiality).

From this we conclude that the perceptual dimension cannot be covered by simple descriptions. It is therefore necessary to characterize the perceptual dimension of materials.

5.1 Perceptual dimension approaches

Our work is based on organization of an exhaustive bibliography of works dealing with the perceptual dimension of materials.

As a result of this study, we can summarize existing approaches to the perceptual dimension of materials; also referred to as materiality. Too often it is reduced to visible materiality. As we are reminded by the book "Materiality", by M. Hegger, H. Drexler, and M. Zeumer [14], materiality has intrinsic qualities (properties specific to each material) and imaginary properties (for example, stone has a connotation of wealth). Another difficulty is that materiality is expressed at different levels. Often, the perceptual quality of materials is covered for facades, i.e. with a surface logic. But materiality is inseparable from a volumetric approach which gives full dimension to the materials by highlighting the different indoor climate.

This complexity of materiality increases the number of approaches concerned.

In our bibliographical study, we distinguish four approaches which each have their advantages and their limits.

The technical approaches, which concern the highest number of works, deal with materials. In general, these books are dedicated to a study of one material [15], [16], [17], [18]. Their objective is to transmit knowledge and skills in the use of the chosen material. At best, the aesthetic aspects only are demonstrated in photos.

The descriptive approach aims to present different projects achieved. The advantage of these books, such as Riera Ojeda and Pasnik's work entitled "Element in architecture: materials"[19], is that they include numerous photos of different projects, classified by materials. In the same way, the article on materials by Pousse and Loriers, in the review Techniques & Architecture, issue 448 [20], describes several projects according to the use of materials.

The poetic approaches are generally books by architects such as Mimram [21], Coste and Orbach [22], or again Zumthor [23], reporting on their perceptions in terms of materials. This approach confirms that for some architects the perceptual dimension of materials has become a key element of their work. However these approaches do not enable designers to assimilate the knowledge and skills required to achieve these indoor climate, these effects produced by the materials.

The analytical approach attempts to overcome this constraint. For example in the book by Moore and Allen [24], the authors describe, comment on and analyze some selected projects. The advantage of this approach is that it gives the designer a method of integrating the perceptual dimension. These methods are based on the main characteristics comprising materiality. We frequently find notions of scale, dimension, space, form or morphology, mechanisms, etc.

5.2 What methods are used to communicate information on the perceptual dimension?

This bibliographical study also enables us to relate the knowledge transmitted and its means of expression.

We note that the practically exclusive use of photos of the selected projects enables designers to draw on ideas. The photos provide an awareness of both the surface of materials and the volumetrics concerned.

However, photography only transmits what the photographers see in terms of the visual aspects of materials, at the expense of the other senses (touch, hearing). In addition photography represents an overall view, in which a vast quantity of information is intermingled.

Another problem with materiality is its subjectivity. As we are reminded by Steinmann [25] the perception of materials is specific to each individual (culture, experience, etc.).

Perception is the process of collecting and processing sensory information.

Some works, usually theses, are the subject of studies on:

- sounsdcapes, particularly the thesis by Raimbault [26] which proposes a method for measuring the subjective by a psycho-physical approach combined with a cognitive approach, then studies language: a vehicle for perceptual interpretation.

- the sensory aspects of architecture. Crunelle's book [12] develops the perception of architecture via three senses, deliberately leaving vision aside, since it tends to dominate the other senses.

- a study of "affective engineering" by Alexandre de Rouvray [27] dealing with Kansei engineering [28], the emotional approaches broadly covered by Desmet [29] and Person [30], the semantic subject approaches developed by Petiot and Yannou [31], and sensory evaluation

These studies demonstrate that there are existing methods that aim to characterize perception. Our task is to develop a method that can be adapted to the perception of materials.

5.3 How should we structure the overall vision of the perceptual dimension of materials?

Based on the different approaches we have identified, we realize that everyone plays a part in transmission of the perceptual dimension of materials. It is therefore necessary to keep all this data. However, its content and interactions need to be structured.

To achieve this, we try to propose an approach that expresses the perceptual dimension.

Stage 1: descriptive approach. This involves selecting reference projects. In other words, we use known projects, recognized for their respect for environmental quality, as a basis. As Péneau [32] says, *"references constitute the corpus of what could be designated as the "project reaction object", constituting as many triggers for the designer's formal choices".*

This stage also incorporates the poetic dimension, if the designers add their testimonials and their visions of the materiality of their project.

Stage 2: analytical approach. Studying these references, to identify their shared characteristics. This means sorting, categorizing and classifying the references. We could, as is often the case, classify them according to their uses, locations, etc., but these classifications are sterile in the sense that they do not allow further analysis. In line with our theme of awareness of edifices, we propose to base our approach on the perception of buildings. We therefore classify them according to their siting, morphology, materiality and spatiality, based on linking concepts. Linking concepts are the result of research works "*From targets to intentions: thinking out relationships between environmental qualities and architectural qualities"* [33]. This notion is based on lexicographical research highlighting twenty concepts based on four key design factors: siting (limits, microclimate, resources, pollution, etc.) morphology (form, footprint, scale, foundation, etc.) materiality (composition, construction, porosity, protection, etc.) spatiality (distribution, partition, communication, regulation, etc.). These linking concepts connect the environment sciences and architecture. Each concept is the fruit of reflection on the environmental implications of different design parameters.

Stage 3: technical approach. We study these linking concepts for an understanding of the architectural mechanisms (implementation processes) used. For example, the concept of "breakaway" uses the "cantilever" mechanism. This term "mechanism" is defined by Gaff [33]: "The notion of mechanism is an analysis tool designed to facilitate our understanding of architecture […]. It constitutes an essential notion in terms of categorizing buildings in types and in styles, and plays an important role in the establishment of our knowledge. […] It constitutes a base for the development of rational reflection on this question, by giving it an analytical framework likely to encourage surpassing the simple individual and subjective sensation".

Stage 4: sensory approach. On the basis of these mechanisms, it is possible to focus on materials. However, the mechanisms fall into two categories: volume-related mechanisms and surface-related mechanisms. We feel that it is important to deal with the materials scale on two levels: the materials level (surface) but incorporating the edifice level (volumetrics) to introduce the notion of indoor climate.Therefore, by accumulating analyses of references for ecological buildings, we create the raw material for the interface by structuring the perceptual dimension of buildings and materials that are inseparable.

6. Interface proposal

6.1 From a repository to a cross-referenced approach

Initially, our tool is a repository, i.e. a set of databases comprising the selected references. It then acquires multiple levels, changing from a single database illustrated by references, to an

analysis of these references. Lastly, organization of these analyses to update, classify and identify the shared characteristics of the selected references, orients us towards a cross-referenced approach. In this way our interface becomes a study method used to construct materiality. To demonstrate this, we need to describe the structure of the interface.

6.2 Interface structure

Stage 1: The reference. This is the raw material of our system. The selection of references is therefore crucial. We have chosen to select architectural projects considered to be ecological. These projects are therefore described by texts, their drawings-facades-cross-sections and some photos showing overall views. These projects may also be commented on by their authors. This gives us their testimonials, their visions of their project, their successes and their difficulties. Lastly, to maintain the spirit of aided design, we can suppose that each project has been entered via applications such as Dial Europe, Pleiade + Comfie, Delta T, etc. so that designers who know the values obtained from their sketches, or who have specific objectives for ecological performance, can draw on the information for the references.

Stage 2: Linking concepts. These represent a classification, a sorting of "reference projects".

The psychological processes of categorization reduce the actual complexity. As shown by the study *"From targets to intentions: thinking out the relationships between environmental qualities and architectural qualities* [...] *they create an equivalence between objects, however different, which we can use to order our understanding of the world by giving it direction"*. [32]

Stage 3: Mechanisms. These analyze families of linking concepts, and highlight their shared mechanisms. Their purpose is to transmit knowledge and implementation skills (technical input). They are mainly communicated by sketches and detailed cross sections. By contrast, they are processed on two levels; surface and volumetric mechanisms.

Stage 4: Sensory aspects and ambiences. These are dealt with on two levels: surface and volume. Surfaces cover the sensory aspects (sight, hearing, touch, etc.) of materials, while volumes allow an awareness of the ambiences produced by the mechanisms. These stages follow on from one another, fitting the materials into the different building levels. However users are free to choose their entry point, then browse the different paths proposed.

6.3 Navigation mode

We therefore obtain a free linear navigation mode. Depending on progress on their work, users may prefer to use different entry points.

For example, from the programming phases though to the initial phases of reflection, analysis of the site may reveal choices in terms of building siting, morphology, etc. By opting for a linking concept directly, users can draw inspiration from "reference projects" to explain and communicate their vision of their own projects.

When the project is more advanced, they can study mechanisms. By understanding how the "reference projects" are constructed, users can adapt these mechanisms to their projects and communicate them.

Today, our interface provides a linear model that class, order..., all the elements and interactions that make up the material. However, navigation aims to develop hypertextual entries. This aims to enabling the user to select at the same time different criteria in different stages simultaneously.

Lastly, when a project begins to take shape, if users have entered their projects into the ecological performance calculation software applications, they can enter these figures to view different buildings producing similar levels of performance.

In terms of materials, in order to adapt to initial project phases, during which this information is not necessarily clear, an independent window can be used if required to select one or more materials to target more precise ambiences and sensory aspects.
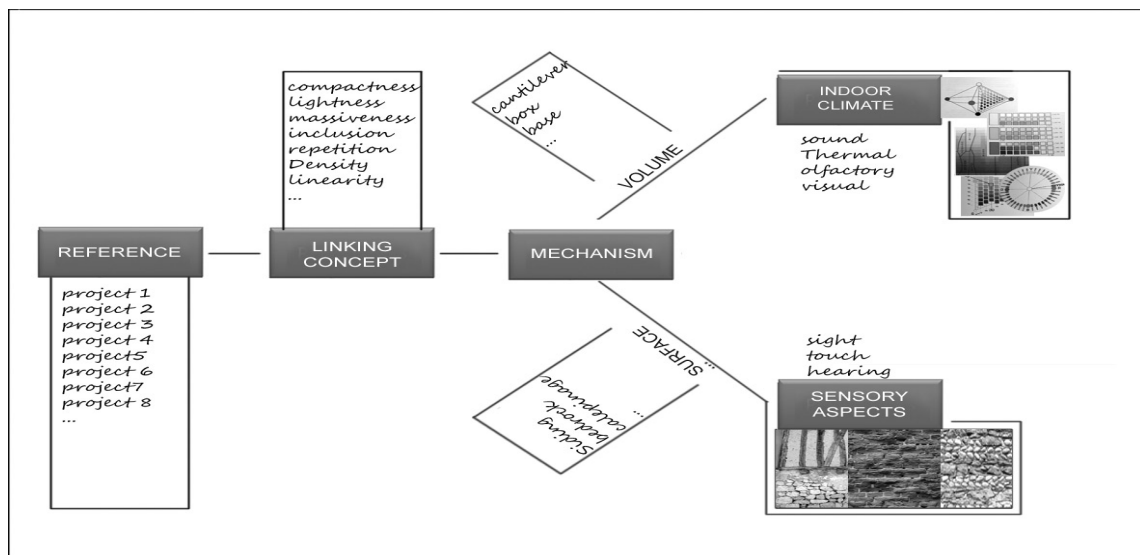

Fig 1. Interface proposal

7. Conclusion and development

This interface involves the laborious work of project analysis, which can be very time-consuming. In effect, to optimize the efficiency of the interface and enhance its data, it will be necessary to increase the number of building analyses.

However, this interface would be improved by processing references up to town scale (town planning and landscaping), for example via the urban fabric approach.

It could be a good idea to combine this tool with an interface used for project entry on the basis of simple data. This would make it possible to qualify ambiences and perceptions according to the specific project characteristics (location, orientation, site, etc.) without having to enter the project in other performance calculation applications. This additional option offers the possibility of including a diagnosis and judgement approach for the designer.

This type of tool would therefore optimize communication, transmission and dissemination of the perceptual dimension. By operating and combining different types of additional interfaces, it would be likely to help designers to qualify the perceptual dimension from the very first project phases. A subsequent phase including surveys of architects in a design situation will confirm this.

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