Building a domain ontology for designers: towards a Kansei based ontology

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Abstract

The information phase is a crucial phase of the design activity. Product designers and engineering designers have regularly to search for and collect inspirational materials in order to enrich the creative process. The TRENDS computer-based system aims to improve this information process. More particularly, this system will support the information retrieval process from the web-based resources, helping the designers to find suitable design (Kansei) information while helping them to identify design trends. This will be achieved through the development of content-based image retrieval facilities based on ontological referencing. The goal of this study is the definition, analysis and description of design knowledge, and experimentation which aims to extract the semantic structure used by the designers during the design process. More precisely, this experimentation explores how designers link images and words using low-level and high-level concepts. The findings are used to build a domain ontology which utilises the relations between semantic adjectives and low-level descriptors.

Keywords: Designer's expertise, design knowledge, Kansei information, domain ontology

1. Introduction

This research is motivated by a study of designers' information retrieval needs during conceptual design phase [1]. The study conducted within the TRENDS research project involves interviewing leading designers of concept cars about their sources of inspiration. The study shows that these professionals require Intranet and Internet image search engines which enable focused search for design specific elements (such as shapes, volumes, colors, and fabrics), enable categorization of information (for example, grouping cars by designer name, period of time, or market segment), and help in illustrating subjective emotions or concepts (for instance, *strength, shock, danger, or fluidity*). To address these requirements, the TRENDS project aims the development of a content-based image retrieval system that utilizes ontological referencing.

The aim of this study is to define, analyze and describe domain knowledge, and furthermore to extract the semantic structure used by the designers during the design process. This knowledge is further employed to construct a domain ontology.

The paper is organized as follows. Section 2 outlines the state-of-the-art. Section 3 focuses on the extraction of design knowledge. Section 4 describes the domain ontology developed. Section 5 concludes the paper.

2. Literature review

2.1 The information phase in early design: the inspirational process

Due to its impact on creativity, the design information phase attracts increasing attention. This is demonstrated by studies of the design process [2-4], design expertise [5], sources of inspiration [6-8], Kansei Engineering [4, 9] and trend boards [10].

The availability of inspirational materials (e.g., images, textures) is crucial to the design process. A core activity of a designer when selecting inspirational materials is the use of semantic adjectives which link words with images and vice-versa. This activity is very specific and could be compared to a hybrid search on both text and images.

Designers recognize that their activity deals

with emotional content, although the process is not necessarily explicit. Their expertise consists in providing emotional effects through design solutions characterized by their semantic expression. Even when they are searching for inspiration sources, pictures they select explicitly or implicitly often have a high emotional impact. In the discipline of design science, semantic, cognitive, and affective elements are considered closely related and constitute an active field of research. However, research centred on the information phase and the inspirational process, does not yet consider semantic and emotional dimensions.

2.2 Semantic based images retrieval

Although content-based information retrieval (CBIR) is a well developed research area, there are very few information retrieval systems specifically dedicated to industrial designers. This can be attributed to the nature of the information designers deal with, i.e. visual and image information linked to particular feelings. Moreover, image retrieving tools are mainly based on visual content processing more related to low level features.

More recent studies in the area concentrate on extracting semantics from images using colour features or lexical databases [11-13] and adopting Kansei Engineering perspective [14, 15].

It is believed that future CBIR systems should support semantic and Kansei based image retrieval which reflects the way designers work. For instance, the use of harmony rules has proved to be efficient for evocation of positive emotional reactions [16]. Even though they are not really formalized and externalized, the rules enabling to link low-level attributes with high-level dimensions are used on daily basis by the designers. This linking task is very subjective and varies from person to person. Consequently, previous systems are often based on a strong interaction between the end-users and the system itself, using images and semantic adjectives. The connection of low-level and high-level dimensions is frequently done with the intervention of the end-users through the use of neural networks [4, 17, 18] or genetic algorithms [19].

The technology enabling semantic based image retrieval is semantic based indexing and annotation.

2.3 Semantic indexing and annotation using ontologies

Semantic document indexing is a way of coding digital texts and images to represent their associated abstract meaning in a database form [20]. It benefits semantic document retrieval which relies on the assumption that the documents are classified using interpretable concepts [21]. Semantic annotation shares similarities with semantic document indexing as it aims to provide some formalization of the content of the documents as a prerequisite for more comprehensive management [22]. The semantic tags used normally utilize a controlled vocabulary and are linked to some semantic descriptions such as dictionaries or ontologies.

An ontology specifies a conceptualization of a domain in terms of concepts, attributes and relations. Concepts are typically organized into a tree structure and are linked through relations forming a semantic net structure. They enable the management of open, sharable, and reusable knowledge which allows automatic interpretation [22, 23] by providing background knowledge and navigation structures for browsing. They support integration of knowledge sources as they build upon a collective understanding within a community. Nowadays, ontologies are collaboratively created across the Web and used to search and annotate documents. Domain-specific dictionaries and ontologies are also used to improve tagging and ultimately information retrieval [24]. Even if the vast majority of the ontology based approaches focus on indexing texts at document level, emergent studies show that information retrieval and concept indexing in particular can largely benefit from the use of ontologies to index documents at word level [25, 26].

Section 3 describes the first step towards building the domain ontology.

3. Extraction of design knowledge

3.1 Requirements

The following is a list of the main requirements towards the TRENDS system defined using the designers' needs [1] and the state-of-the-art review presented in Section 2.

(1) The TRENDS system shall correlate high level dimensions like concepts, semantics and affective reactions with low level image features.

(2) The TRENDS system shall use semantic adjectives for retrieving images.

(3) The keywords used shall be structured according to a purpose built domain ontology dedicated to design expertise.

(4) The domain ontology shall be linked to the established sectors of influence following the Conjoint Trends Analysis (CTA) methodology [27].

3.2 Nature of design knowledge

Design information is progressively integrated in the intermediate representations and models used throughout the design process. It is supported by different media such as conversations, text, images, or sketches [7] which are stored both in physical

and digital databases. Images are more difficult to manage than words because of their holistic nature. Indeed their meaning can not be separated from the whole. Moreover they allow for a multiple interpretation of their content. This is due to the attention, selection and categorization mechanisms that our brain uses in filtering, organising and storing information.

The contents of design information includes low-level descriptions of design features like colour (hue, saturation, brightness), shape, high-level descriptors like semantic adjectives expressed in metaphors based on analogies to other domains, and affective responses involved while visualizing low-level information. These high-level descriptions, abstract by nature, result from inferences by the application of categorization principles enabling to extract semantic information from specific design content. They correspond to sophisticated design features resulting from the application of definite design skills to develop particular aesthetic qualities [7]. Such kind of high-level information can be more influential with respect to the decision processes of the consumer of the product than more concrete information.

3.3 Extracting design knowledge in TRENDS

A concept is a both concrete and abstract representation synthesizing many objects by the abstraction and generalisation of recognizable common features from different domains or categories. Images contain concepts that can be characterized by their semantics which is itself related to particular low-level features. Its description depends on the context and also on the individual subjectivity. That is the reason why the definition of design ontology should be based on a semi-automatic process enriched by a learning approach. The active participation of the end-users in this process is required. Designers' mental models are implicit. A first step for a computer-based information retrieval system is the externalization of the designers' mental models into formal representations in order to be able to translate them into algorithms. A previous study [4] proposed a conceptual design space based on low-level categories, to allow users to dynamically transform their mental models into formal specifications understood by an intelligent agent and usable by a computer. The agent starts describing each image based on the low-level categories, through the use of image processing algorithms. Then a hierarchy of neural networks is used to learn the mapping between basic categories and high-level concepts (semantic adjectives). In order to reduce the fuzziness of the impression words, a specialization process is necessary. It is performed at two different levels: the category of the objects observed (images of landscapes vs images of cityspace) and the meaning of the impression word (cold as emptiness or cold as a temperature). The detection of clusters on image categories creates a specialization of the word directed to the field of application, while the detection of clusters on low-level features aims to detect different uses of the same impression word. The creation of independent models for *romantic city* and *romantic* landscape for example can reduce the complexity of the modelling process for the word *romantic* [18]. The extraction approach in the TRENDS project is based on the direct manual annotation of images by car designers. Correspondence tables are used to show verbally the semantic relations between high and low-levels features. The overall protocol includes the following steps [1]:

1. Magazine-based search: inspirational value evaluation and categorization
2. Web-based search: inspirational value evaluation and categorization
3. Focused image-search with brief
4. Free description of images

The user tests were performed with 4 professional car designers. The experiments aimed at observing end-users' way of associating words and pictures. The experiment was conducted in the following way. First the designers had to search pictures that they considered inspirational (cases 1 and 2). These pictures were not specifically related to car design. They were chosen by the designers themselves from the various magazines and websites they used. These magazines and websites refer to the sectors of influence for car design. Therefore, the selected images can be considered representative of the inspirational processes routinely used during the design process. Designers in the experiment had to provide an argumentation of the reasons why they have selected each of the images. Next, the designers had to conduct a focused image search following a specific brief. Finally they had to provide free descriptions of the selected images. The inspirational images found in magazines and web sites are later manually annotated using Kansei words. The process in illustrated in Fig. 1

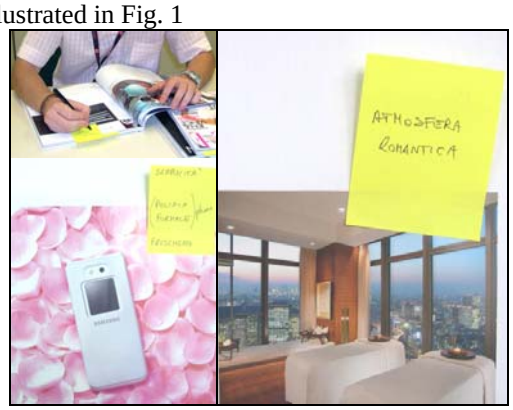

Fig. 1 Kansei words extraction: manual annotation of images from magazines by the designers.

4. Specification of the domain ontology

The experimental output was summarized using tables containing pictures and their annotations. The annotations were obtained by presenting the designers with pictures selected by the experimenters, and asking them to verbally describe the images. Table 1 shows the Kansei descriptors attached to five images from different domains.

Table 1
Manual extraction of Kansei words

	**Designers words 1** *Opacity* *Motionless* *High-quality beer* *Quality* *Fresh* *Clean image* *Immediate* *Simple* *Summary*
	**Designers words 2** *Geometry* *Bizarre* *Cubist* *Dynamic* *Presence* *Impressive structure* *Impact of modernity* *Funny* *Sculptural* *Uninhabitable*
	**Designers words 3** *Relaxed* *Freedom* *Cool* *Private room* *Comfortable* *Dynamic* *Fresh* *Entertaining* *Versatile* *Loft spirit* *American*
	**Designers words 4** *Transformation* *Modern* *Food* *Modern food* *Bright* *Fresh* *Greenhouse effect prevention*
	**Designers words 5** *Communication* *Old-fashioned* *Vibrant* *Confusing* *Product oriented* *Kitsch* *British*

The resulting list of words encompasses all representative types of Kansei information. It includes *high-level* descriptors like sociological values, semantic adjectives and also metaphorical concepts. In addition to the semantic adjectives, concepts representing sector names (*food, product),* and values (*freedom, modernity, greenhouse effect prevention)* were also evoked.

Designers very often describe design representations with semantic adjectives. This kind of adjectives is strongly based on analogical reasoning. It often refers to external references that have a direct impact on the *low-level* features of the representations. In the observed case, some semantic adjectives are linked to *low-level* features. Examples include:

- shape and volumes: *cubist, sculptural*. In addition, symmetric shapes are representative of the notion of *motionless,* and dissymmetric shapes correspond to the adjective *dynamic*.
- texture: *opaque, vibrant, bright*.
- color: *not expressed here.*

Designers also refer to more abstract concepts like originality *(fresh, modern, bizarre, funny),* comfort *(comfortable, cool, relaxed),* styling *(kitsch, simple)* or country culture *(British, American)*. Originality is very dependent of the difference between the proposed design solution and the current *high-* and *low-level* references in the field: the building described by *Designers words 2* reveals this property of going out of the well known references. Usual volumes should be basic cubes or parallelepipeds. The proposed solution is based on a specific influence coming from painting and sculpture. The building has been designed so that it is viewed from multiple views. Some of the parts seem rotated or moved and then re-assembled. The surfaces intersect at apparently random angles in a non coherent sense. The novelty of this solution in the field of architecture makes it original, even if the phenomenon is well known in other fields.

These outputs were further used as specifications in order to build the design domain ontology. Table 2 shows the verbal correspondence between designers words and design elements. This correspondence has been established by two experts in Kansei engineering. It is used there in the sense of a generic interpretation. In the field of Kansei engineering, the correspondance between *high-level* and *low-level* concepts is based on *design rules*. Table 2 shows several design rules.

In fact the multi-sectorial sources led the experimenters towards the elaboration of a generic correspondence table, because the inspiration sources by nature are extremely miscellaneous. However domain knowledge extraction enables to define more precise design rules, when studying the reference objects.

Table 2
Verbal correspondence between designers words and design elements, towards a "Kansei dictionnary"

Designers word	Related words	Design element
Simple	Clean	Elemental geometrical volumes Plain colours
Dynamic		Dissymmetric Tense lines
Original	Fresh Bizarre Funny	Formal distance to the reference archetype (colour, form, texture)
Relaxed	Comfortable	Curves with big radius of curvature
Motionless		Symmetrical
Kitsch	Loaded	Many objects
Freedom	Irregular Unconventional	Non regular forms / volumes
Quality	Clean	Texture finishing, coatingwith visual and tactile effects

In the TRENDS project, both generic and specific domain ontology is being built, thanks to the experience of the authors in various fields of design. The generic one will give birth to a Kansei dictionary, aiming to link semantic adjectives with design elements. A complementary literature review of 47 studies revealed the most used semantic adjectives in the scientific studies related to images retrieval. These are shown in Table 3 (arranged by their occurrence frequency). Currently, the most frequently quoted adjectives for image retrieval are mainly linked to colors.

Finally, the domain ontology is developed by creating instances and linking them in terms of the abstraction, aggregation, and dependency-based semantically-rich relations using Protégé software.

5. Conclusions

This paper shows the research underlying the development of domain ontology for the purpose of assisting designers in finding inspirational materials. It reveals the process of extracting design knowledge and most importantly the semantic structure used by the designers during the design process. The experiments explore how designers link images and words using low-level and high-level concepts. The findings are used to build a domain ontology which utilises the relations between semantic adjectives and low-level descriptors.

Table3
Most common semantic adjectives used in information retrieval

Adjectives	Related words	Impacted low-level features
Natural	Simple Authentic	*Colours:* natural colours (green, …)
Warm		*Colours:* warm colours (orange, …)
Romantic	Glamour	*Colours:* unsaturated colours (pastels)
Heavy		*Shape:* dimentional ratios
Bright	Brilliant	*Texture:* reflectance
Cold		*Colours:* cold colours
Dark		*Colours:* dark colours
Dynamic	Active	*Shape:* dissymmetry
Heavy		*Shape:* dimentional ratios
Beautiful	Aesthetic Gorgeous	*Shape:* use of formal harmonies *Colour:* use of chromatic harmonies
Classic	Traditional	
Clear	Clean Pure	*Colours:* white, light greys
Elegant	Refined	
Exciting	Seductive Appealing	*Colours:* saturated colours
Light		*Shape:* dimentional ratios *Colours:* light colours
Simple	Basic	*Shape:* elemental geometrical volumes *Colours:* plain colours
Soft	Light	*Shape:* curves *Colours:* pastels *Texture:* smooth matter

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