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AESTHETICS AS PARAMETER OF INTELLIGENT DESIGN SUPPORT

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1. Introduction

It is hard to imagine a modern design process without using a computer. In fact, Computer Aided Design (CAD) is so extensively applied that in many companies all design work is done using CAD systems. Yet, there is a body of opinion that the benefits of applying CAD are bellow expectations. We believe the reason for this lies in the fact that the existing CAD systems are still not yet adequate as a proper aid to the designer in the process of designing a new product. The way in which it is hoped to overcome this bottleneck is to increase the intelligence of CAD systems [Sancin et al. 2008].
It is becoming increasingly evident that adding the intelligence to the existing computer aids, such as CAD systems, leads to significant improvements of the effectiveness and reliability at performing various engineering tasks, including design. Actually, Artificial Intelligence (AI) applications to design are reality and subject of intensive development and implementations [Luger 2009].
Design data are not always well formulated, and almost never complete. Experienced designers can deal with such data reasonably easily, while even the most "intelligent" programs have great difficulties. Designers are also reluctant to assign responsibility for decisions to computer programs, no matter how competent they may appear. One can also argue that encoded design knowledge does not allow designers to express their creative ideas.
This is even more important in some specific design areas that have their specific constraints and criteria and therefore require specific approach in design process. For all these reasons, computer (intelligent) support to specific design aspects, including those that are subject of the proposed paper, is still quite limited and therefore insufficient.
In continuation of this paper aesthetic design will be presented from »intelligent design« point of wiev. Aesthetic parameters will be formalised, so they could be used to develop the knowledge base of intelligent advisory system.

1.1 State of the art

The aesthetic design phase, also called styling, still represents a serious bottleneck in the CAD process chain, as product designers do not have any serious commercial computer aided aesthetic design software at their disposal. Thus, designer has to trust to her or his aesthetic abilities and feeling in order to perform product design of complex-shaped products like car hoods, consumer appliances, toys, packaging, etc. It is very hard to define a procedure that would assure acceptable results of the aesthetic design process. Two European projects: FIORES and FIORES-II (FIORES - Formalisation and Integration of an Optimized Reverse Engineering Styling) aimed at building innovative CAD tools that adhere to the creative user mentality and at improving the cooperation between the main players involved in the product development process, by identifying shape properties directly affecting the aesthetic character, and by providing modelling tools for their evaluation and modification [Giannini et al. 2006].

However, there is no computer software available to offer exper help to the designer in aesthetic design phase.

1.2 The aim of the paper

As argued before, expert help in field of aesthetic design is needed. In order to present the problematic of this field, the paper presents brief theoretical background on aesthetic design from designers' point of view, framework for formalization of aesthetic component of certain design and proposal for intelligent decision support system in field of aesthetic design.

The aim of the paper is not to discuss aesthetics from philosophical point of view, but to present problematic of aesthetics trough eyes of the mechanical design engineer, who is responsible for outer shape of the product already in conceptual design phase, where various influential factors determine the design.

2. The theory of aesthetics in design

In the process of designing a product the aesthetic component of the product in most cases is not the main objective, as would it be in a artistic creation, which aims to achieve a high aesthetic value. The aesthetic component is a resultant of design parameters that determine the basic characteristics of the designed product [Papanek et al. 1974]. The designer must develop the aesthetic component of a product included into the basic product concept through the entire creative process. Aesthetic value is formed by the elements (design solutions), which characterize the perception of the product, while challenging the subjective feelings of the user - the observer, which can be called aesthetic. The (apropriate) creation of aesthetic component is influenced by various influential factors, which can basically be divided (combined) into two major groups [Kaljun et al. 2007]:

- *Subjective factors*; the basic concept of aesthetics (philosophy) is bound to subjective perception. Subjective factors are closely linked to potential users and therefore relatively difficult to measure. They are formed by personal and cultural norms that apply in the environment originating the potential users. A large part of successful design depends on the designer's knowledge of the environment in which is the product going to be intorduced. Different psychological and philosophical studies, which the designer can use in their work, can be very usefull.
- *Objective factors* are a kind of "universal" measure of aesthetic value of each product. Objective factors dictate the aesthetic elements and relations between them, which can be called the building blocks of harmony. This group of factors includes, among others, functional factors such as clear shape, which is adapted to the main function of the product, to increase the aesthetic value of it.

2.1 The impact of the aesthetics to product development

Naturally, the impact of aesthetics as one of the design goals (a kind of added value) can not be simply left to chance, but has to be considered already in the concept stage of product development. Required aesthetic value and guides to achieve these values must be, with other requirements in the areas of ergonomics, the mechanism of the structure and functions, well known and clearly defined already in the definition of development task, to allow designers to simultaneously satisfy all the requirements. Designers' task is to develop aesthetic elements in accordance with already presented factors.

The relationship between "technical" and "aesthetic" value of a product is defined by the purpose or mission of the product. The link between the technical - economic value and aesthetic - artistic value can be presented as the field of aesthetic value, which grows with the sidestepping of the basic machine elements towards consumer products, where products can be found which, together with the main function, provide even prestigious funciton.

2.2 Aesthetic elements

Most usual aesthetic guidelines in product design includes “soft curvatures” and “warm colours”, perhaps indicative of a specific evolution-induced predilection for “naturalistic” forms and hues. For some designs these guidelines might actually bring satisfactory solutions. For other more complicated demands, the designer has to know and use certain more-detailed guidelines. In order to understand the extent of aesthetics, we will divide it into three types of elements, as shown in Figure 1.

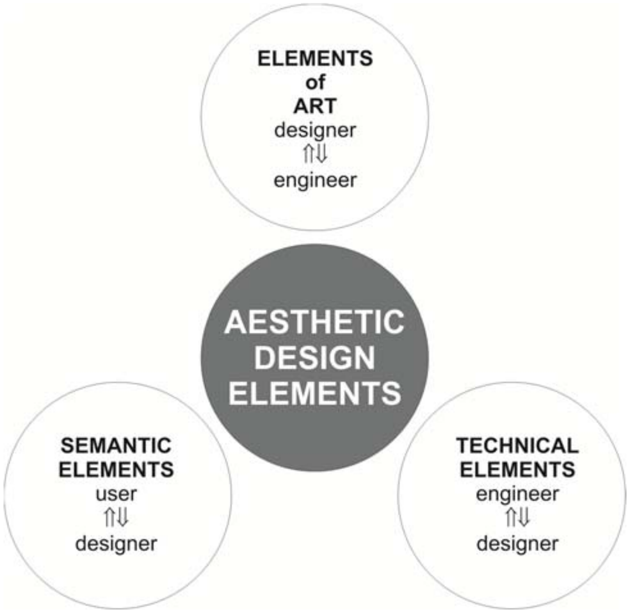

Figure 1. Aesthetic elements

The first and foremost element type is the Elements of art, a set of techniques that describe ways of presenting artwork. The elements of art can include many or all of the following artist's concerns: colour, value, line, shape, and texture.

They are combined with the Principles of art (movement, unity, variety, balance, emphasis, contrast, proportion, and pattern) during the production of art.

The composition of elements of art, which form the shape of the product, can be described through Semantic elements, or the elements of form acceptance. The purpose of the semantic elements is to translate the composition or its parts to the user's (observer's) understandable language [Crilly et al. 2004]. Reversely a designer can, on the basis of the known - the desired semantic elements (communication of the product), build an appropriate composition of art elements.

Since an exact description of the art elements and composition is very important in further developing the product, the desired aesthetic value can only be accomplished by maintaining the intended composition. Therefore, it is necessary to transform the elements of art to Technical elements, which represent a form of instruction for the technical execution of each element of art and overall composition, respectively.

2.3 Product semantics

Product semantics was introduced by Krippendorff and Butter [Riley 2001] and is defined as the study of symbolic qualities of man-made shapes, in the cognitive and social context of their use. Thus, according to this definition, product semantics is concerned with the relationship between the user and the product on one hand, and the importance that objects assume in an operational and social context on the other hand. Intentionally or not, all manufactured products make a statement through shape, form, color, texture, etc. They communicate with users and can never be contextually neutral. It is widely recognized that visualization is important when it comes to assessing the feasibility of a product in terms of appearance, functionality, production feasibility, product semantics, ergonomics and social factors. Regardless of how designer use color, shape, form, and texture in designing the product, messages are being sent through products via a part of language structures that deal with meaning, called semantics. This implies that designers and ergonomists should not only know what message(s) they wish to transmit and the sort of response(s) that can be expected from the user being the receiver, but also the symbols and attributes forming that language.

Product semantics can be represented with three groups of functions (Figure 2):

- formal aesthetic functions,
- signal functions and
- symbolic functions.

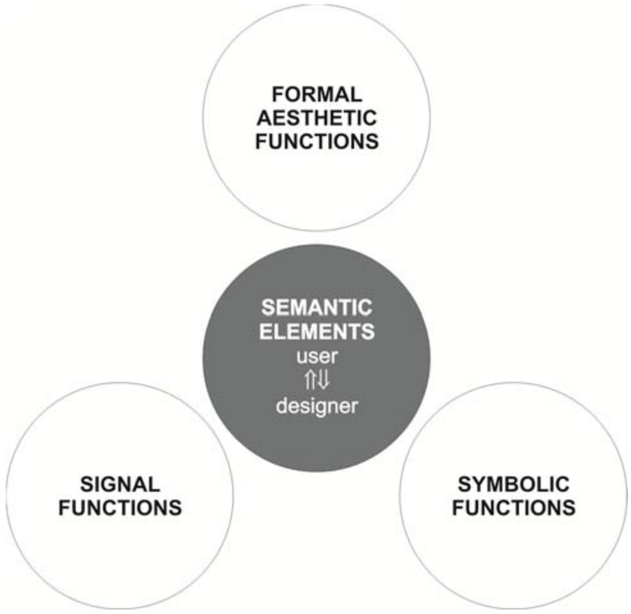

Figure 2. Semantic functions

Combination of presented semantic function has to make the product comprehenible. Therefore, both the whole product and its individual parts should express the desired (intended) message. When product semantics is properly applied, products can become more emotionally and psychologically comfortable for users, with expressive shapes or details, allowing them to make emotional connections with otherwise impersonal objects. Proper use of signal and symbolic functions on specific parts of the products (knobs, buttons, handles, etc.) reflects in intuitive products where the user knows how it works and what it does without instructions.

3. Aesthetic design objectives

When analyzing the market and the anticipated requirements of customers, including estimates of the target groups regarding the developed product, the designer must have clear aims regarding the aesthetic component, and must define the semantic message of the product's visual identity. Defining the semantic forms of communication is very important, if not the key to mass produced consumer products, where the main function also complements the so-called prestigious function. The duty of the designer is to create such a product shape that best reflects the desired message, and follows the requirements of the relevant components regarding the aesthetic quality of the product. Aesthetic recommendations for the designs of products can also be an assistance and support to the designer. Aesthetic recommendations can be collected in the form of those aesthetics objectives in design, which bring together art, technical and even semantic elements. These objectives are:

1. shape is consistent with the function (form follows function)
2. shape has the desired compositional consistency
3. shape reflects the planned semantic message

3.1 Functionality of the product

At the end of the 19th century, the phrase "Form follows function" was mentioned for the first time and became the 20th century leading thought in the field of industrial design. Indeed, it is in the "first plan" when developing industrially manufactured products regarding implementation of the main function, while the shape of the product mostly serves its ergonomic suitability and visual appearance.

In practice this means that, the coffee grinder is intended primarily for “user friendly” coffee milling, and not decorating kitchen shelves, while expressing its identity and brand affiliation, among other things with their visual image [Quarante et al. 1991].

Design recommendations in the field of aesthetics, in this case are:

- the form indicates how to use the product,
- the form of the product allows easy and safe use,
- the control areas are easily accessible,
- the use of different materials can add further functional highlight.

3.2 Compositional consistency

Combined with the known main function of the product, the designer has to compose a visual image of the product in such a way that it generates pleasant feelings and desires when used or merely possessed by the user, as well as the observer. The principles of visual composition are also present, in certain respects, in the designs of industrial products.

Thus, the objective compositional consistency can be archived by:

- the individual elements that constitute to the whole (in the form of a product) yet are mutually dependent so that the established rhythm, expresses the desired message (movement, resting ...).
- tendencies derived through individual elements must conform to the overall composition of the product.
- the proportions used should be in accordance with the principal function of the product:
- where possible, usage of pleasant (real) proportions is desirable,
- the use of different proportions on the different elements of one product is undesirable.

3.3 Semantic consistency

While the first two objectives of aesthetic design the care about subconsciously receiving of the product, semantic consistency carries, in concept stage already known, message of the product. Semantic message is reached with applying certain values of selected technical elements to the shape of the product. Some recommendations are presented in Table 1, while the graphical presentation of technical elements can be seen in Figure 3.

Table 1. Design recommendations for semantic consistency [Kaljun et al. 2006]

The technical element	communication form
acceleration	aggressive, speed sports
hollow, crown	power, aggression, tension
convex, concave	tense
sharpness	tense, aggressive
tenderness	tense, natural, organic, warm
crispiness	cold, aggressive
tension	tense, wild
lead in	aggressive, threatening

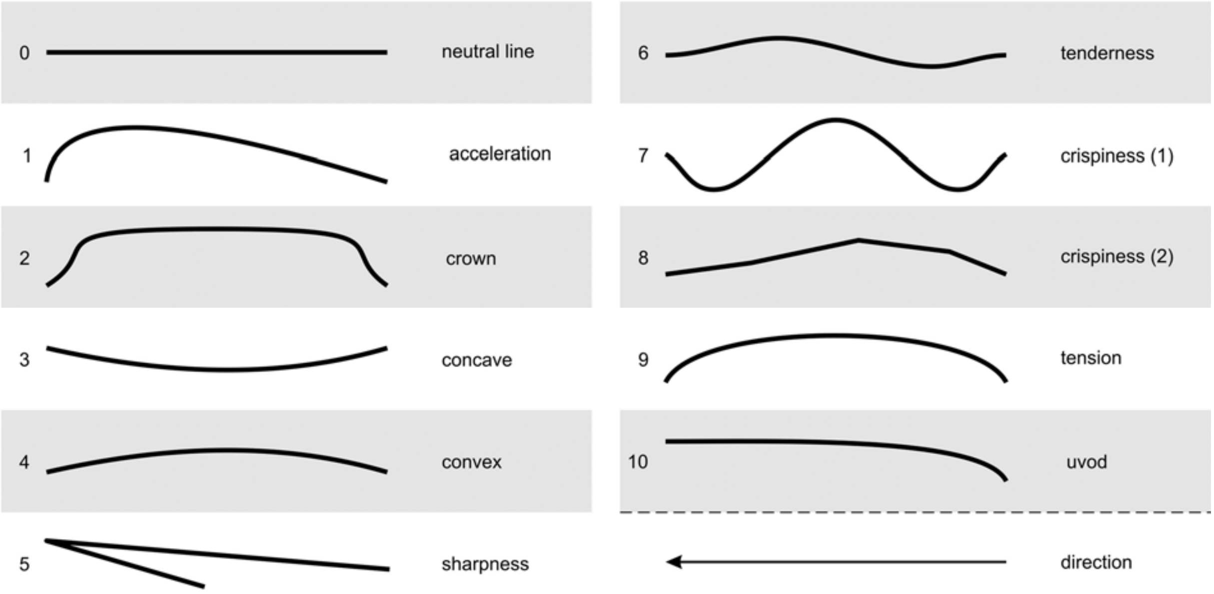

Figure 3. Graphical presentation of technical elements

4. Intelligent support to ergonomic design process

Various advanced approaches have been investigated to improve product development process. The need for integration of ergonomics into product design is evident for quite a long time now. However, the need for knowledge-based decision support within ergonomic design process has been defined more recently. It is based on cognition that conventional CAD tools do not meet the expectations of design engineers. While they offer reasonable level of support in various design analyses, they fail to provide any kind of meaningful advice from engineering point of view in terms of design recommendations leading to better aesthetic value of the product, when appropriate.
In order to overcome this bottleneck and to round off a cognitive cycle for continuous improvement of product's aesthetics, we are developing a prototype of an intelligent advisory system Oscar, based on expert design knowledge management.
Possible logical frame of design knowledge management has been proposed by Du et al. at Computer-Aided Industrial Design & Conceptual Design conference in 2009 [Du et al. 2009]. In the proposed frame the aesthetic appearance of the product is not considered as an influential parameter, which however is the case in our system. Oscar is namely composed out of two sub-systems (Figure 4) that can be applied in two different modes. We can use them independently from each other, or simultaneously and interdependent on the same design project.

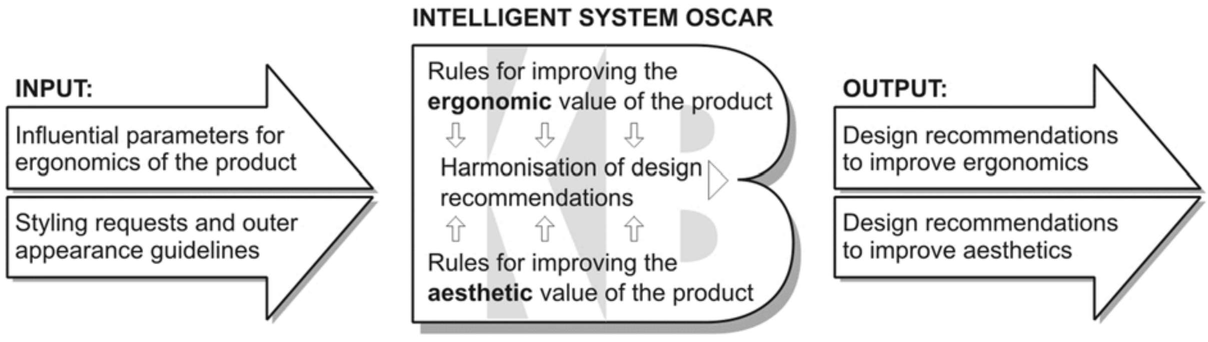

Figure 4. Basic structure of the intelligent advisory system Oscar

In the simultaneous mode, the task of the inference engine is not only to derive and propose recommendations for both, ergonomic and aesthetic design improvements, but also to synchronize and

harmonize possible design solutions in order to find the optimal balance between the two aspects of the product being developed.
The intelligent decision support system Oscar is still a research prototype, and as such, a subject of intensive development, especially more subjective part of the system dealing with engineering aesthetics and aesthetic ergonomics.
Basically, the intelligent advisory system Oscar is a computer system that emulates the decision-making ability of a human expert. Such intelligent systems are designed to solve complex problems by reasoning about knowledge, like a human expert, and not by following the procedure of a developer as is the case in conventional programming.
The structure of the intelligent advisory system Oscar is unique, and significantly different from traditional programs. In foundation, the system is divided into three parts. The first part is fixed, independent of the rest of the system, called the inference engine. The second part is variable, called the knowledge base. The third part, which serves as communication module is called user interface. When running Oscar, the inference engine reasons about the knowledge base like a human expert and communicates with user through user interface.
In the intelligent advisory system technology, knowledge base is expressed with natural language IF-THEN styled rules, called production rules.
Oscars' inference engine runs in so called conversational mode. This simply means that the inference engine requests initial data from the user at the start. Since problems are usually complex, system often cannot find a suitable solution using only initial data. Therefore the system has to find the way to solve the problem by requesting the missing data form the user.
With additional data system gradually approaches to the solution. The user feels like a participant in a dialogue led by an expert. To control a dialogue, the inference engine applies three different techniques: forward chaining, backward chaining and mixed chaining [Chein et al. 2009]. Forward chaining is a technique where the inference engine searches the solution (goal) by using specified procedure and asking questions. In backward chaining, the inference engine knows the solution and attempts to find production rules to support the solution. In mixed chaining the inference engine has an "idea" of the solution but cannot simply confirm it. Therefore the inference engine deduces in forward chaining technique using information from previous user responses before asking the next question. So quite often the inference engine deduces the answer to the next question before asking it.
When developing Oscar, a development environment named Exsys Corvid [Awad 2003] has been used. The Corvid enables developer to build the knowledge base using natural language. User interface is built simultaneously with knowledge base. The Corvid provides developer with configurable inference engine. The prototype is built as java applet to be used online.

5. Conclusions

Some aspects of product design, such as aesthetics, which were in the past often unduly neglected in comparison with functional and economical efficiency of a new product, are now becoming increasingly essential.
Designers have the obligation to fashion the product to specific guidelines, regulations, standards and other elements in early developments stage, so that at the end, a product will be successful on the market. This is a difficult task for people whose job should be oriented into creative development of new goods rather than constantly studying certain rules.
Aesthetic design is a vital and complex part of product design process. In view of the complexity, multi-factors coupling and fuzziness of aesthetic knowledge, an intelligent support to aesthetic design in form of advisory decision support system is proposed.
In this context, the knowledge related to aethetic design has to collected, organised and encoded in form of production rules, which were found to be the most appropriate formalism due to their transparency and closeness with the human way of decision making process.
The knowledge built in the prototype of the intelligent system named Oscar is structured in form of different classes interconnected with various attributes and their values at the input side, while as the output of the system the user can expect (re)design recommendations leading to achievement of certain design goals that can improve the aesthetic value of the product being developed.

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