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Using evolutionary design to interactively sketch car silhouettes and stimulate designer's creativity

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ABSTRACT

An Interactive Genetic Algorithm is proposed to progressively sketch the desired side-view of a car profile. It adopts a Fourier decomposition of a 2D profile as the genotype, and proposes a cross-over mechanism. In addition, a formula function of two genes' discrepancies is fitted to the perceived dissimilarity between two car profiles. This similarity index is intensively used, throughout a series of user tests, to highlight the added value of the IGA compared to a systematic car shape exploration, to prove its ability to create superior satisfactory designs and to stimulate designer's creativity. These tests have involved six designers with a design goal defined by a semantic attribute. The results reveal that if "friendly" is diversely interpreted in terms of car shapes, "sportive" denotes a very conventional representation which may be a limitation for shape renewal.

1. Introduction

The art of sketching, and the sketches themselves, are considered to be an important part of conceptual design as well as the way for designers to condense their knowledge and exploration (Römer et al., 2000; Tovey et al., 2003; Yang, 2009). In their work, Yang et al. (Yang and Cham, 2007; Yang, 2003) address the correlation between the quantity of generated sketches and their impact on design outcomes. Moreover, they explore the relationship between the moment of sketching in the design process, especially early in the design, and the impact on the outcomes. Based on the correlation coefficient exploration, statistically it is found that the quantity of concept generation is significantly correlated with project outcome quality. This is also the case for the timing of sketches: Yang (Yang, 2009) found that early sketching and prototyping gave the best project outcome qualities. Moreover, some studies focus on the importance of the prototyping stage. Yang (Yang, 2004) explores the influence of the prototype complexity, prototype quantity and the time spent on this activity and their relationship with the design outcome. The results of the study show that the lesser number of parts in a device, then the greater the project outcome quality.

Evolutionary Computation (EC) has become a major approach for the exploration and evaluation of design solutions, and especially 2D sketched solutions. An EC method basically uses the genetic algorithms (GA) (Bentley and Corne, 2002; Renner and Ekart, 2003), which were originally used to find solutions for complex optimization problems. For example, Poirson et al. use GAs to optimize the design of brass musical instruments by considering mathematical and perceptual objectives (Poirson et al., 2007). Taking the evolution in nature as a paradigm, the GAs work on the basis of a population of individuals, where each individual represents a possible solution for the initial problem. The structure and qualities of each individual are encoded in their genomes. Through the recombination of these genomes individuals can reproduce themselves and produce new individuals (solutions), and through a sort of natural selection, individuals who are not adapted to the environment (whose properties do not satisfy the expectations) are not selected for procreation. In this way, individuals display better and better qualities over the generations. Interactive Genetic Algorithms (IGA, see (Nicaise and Antonsson, 2007; Kelly et al., 2008)) represent a special class of GAs where a human (here, the style designer) is a key player embedded within the task of selecting individuals from a generation. IGAs are then particularly adapted to situations where it is impossible to explicitly express a preference function (the fitness function) on individuals or even when it is hard to qualify expected properties. This is typically the case with style designers.

A major difficulty when using GAs in automatic design systems is the encoding of the genome (see (Nicaise and Antonsson, 2007)), which means the way of coding the individual's phenotype (physical structure) into the genotype (genome). Most systems use a direct encoding where the geometrical

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dimensions and structures of the design object are directly represented in the genome (see for example (Kelly et al., 2008)). For example, when designing a bottle (Ang et al., 2006; Kelly et al., In press) or when finding a design for cylindrical shapes (Yanagisawa and Fukuda, 2003), the phenotype is represented in the genome by a sequence of geometrical parameters such as the radii, lengths and part locations. Consequently, encoding is context dependent. Other works use tree structures (Liu et al., 2002) or shape grammars (Osborn et al., 2006) to encode the genome. Kim and Cho (Kim and Cho, 2000) have used a set of predefined parts of clothes to find new fashion designs by recombining these parts. In addition, all of these systems are conceived for a given design domain. Implementing these methods in new design fields is a difficult and time consuming process. However, a good design method should be applicable, as much as possible, to a large spectrum of situations.

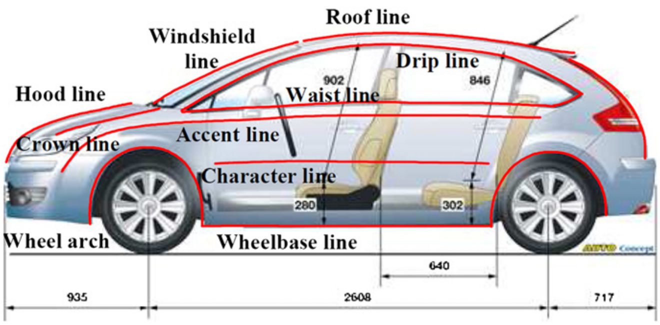

Fig. 1. Cheutet models a car using key lines (Cheutet, 2007).

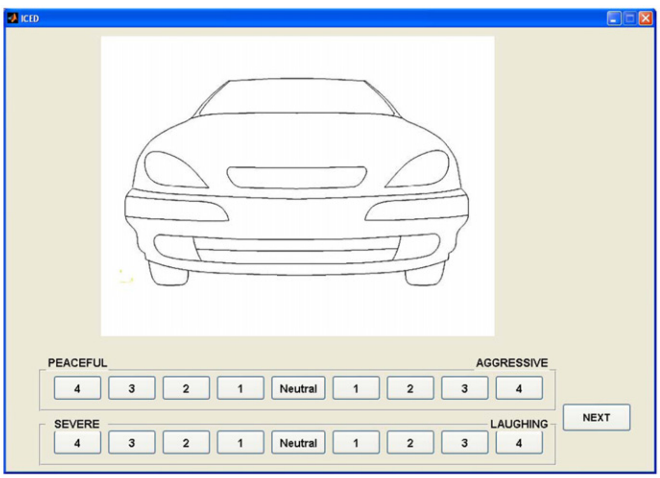

Fig. 2. Perceptual evaluation of car front-end designs by Petiot and Dagher (Petiot and Dagher, 2010).

In this paper, we first propose an encoding method for a 2D-closed-curve which is supposed to meet a desired style. This method can be applied to all possible objects represented by their 2D-silhouettes. For instance, a car silhouette or profile is an essential style feature for a car. Indeed, Cheutet (Cheutet, 2007) has shown that the character of a car profile is primarily expressed through a series of about ten lines (see Fig. 1). Five of them: hood line, windshield line, roof line, wheelbase line and wheel arch, may be merged into a silhouette closed line. It has been proved that these lines, and especially the silhouette, have a strong determining influence on the perception of the car while embedding perceptual attributes such as: sportiveness, aggressiveness or peacefulness, etc.

In addition, it has been proved that the esthetic aspects of a car amounts for 70% of customers purchase intents (Cheutet, 2007). Other approaches consider car shape design in a tool for assisting the designer. Petiot and Dagher (Petiot and Dagher, 2010) propose a tool to evaluate car front-end designs through semantic attributes (see Fig. 2). Osborn et al. Osborn et al. (2006) use shape grammars to assist the user in the design of new car profiles (see Fig. 3). Kelly et al. Kelly et al. (2008) describe a car silhouette with 12 points (8 fixed points and 4 varying points) and use an IGA to find new designs (see Fig. 4).

Consequently, it turns out that the design of car shapes or silhouettes has been studied with different techniques, one of them—Kelly et al. (2008)—is even with an IGA. In this paper we

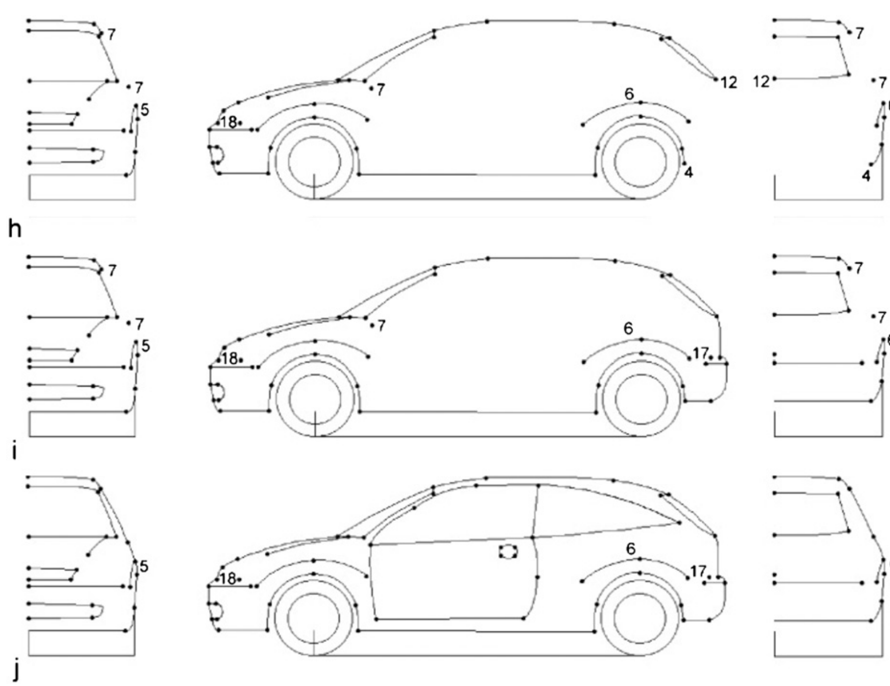

Fig. 3. Some stages to build a Ford Focus using the shape grammars defined by Osborn et al. Osborn et al. (2006).