Digital Styling for Designers: in Prospective Automotive Design

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Abstract. Although a great part of the new-product development process in automotive industry is already digitalized to some degree, the level of digitalization of the styling process is not so high particularly in view of concurrent engineering. This paper is (1) to investigate the state-of-the-art of computer-aided styling (CAS), (2) to propose desirable CAS guidelines reflecting the characteristics of the automotive styling process, and (3) to suggest three possible CAS alternatives based on the guidelines: (a) the digital design sketch, (b) real-size spline curve modification system, and (c) direct 3D shape creation method for professional automotive stylists.

1. Introduction

The automotive industry has been traditionally well structured, and recently highly digitalized for more effective manufacturing. In the car-body styling process as well, there has been a great deal of digitalization effort, in the name of *computer-aided styling* (CAS). At present, raster-type 2D graphics S/Ws are used for the concept selection and embodiment design stages, and reverse engineering, CAD S/Ws for the detailed design stage. Lately, many automotive design studios are introducing a high resolution large-display H/W, so called a *power wall*, for evaluating a final (or semi-final) design shape and/or inspecting its surface quality [4].

However, the automotive styling process still depends on conventional (analogue) methods rather than digital ones, and even digital systems have a serious problem considering from a *concurrent engineering* standpoint – there is *no* digital connectivity among them (see Fig. 1). Thus, this paper presents (1) some guidelines for a desirable automotive CAS environment that enables a fluent digital-data flow, and (2) several CAS alternatives based on the proposed guidelines.

The organization of the paper is as follows: In Section 2, previous research about CAS is summarized. Based on the characteristics of the automotive styling process considered in Section 3, three guidelines for a harmonious digital styling process are proposed in Section 4. In Section 5, new digital methods for automotive styling, which follow the proposed guidelines, are given: (1) the *digital design sketch*, (2) *real-size* spline curve modification with *graspable handles*, and (3) *direct* 3D shape creation based on the *perspective 3D sketch*. Discussions and conclusions in Section 6 close the paper.

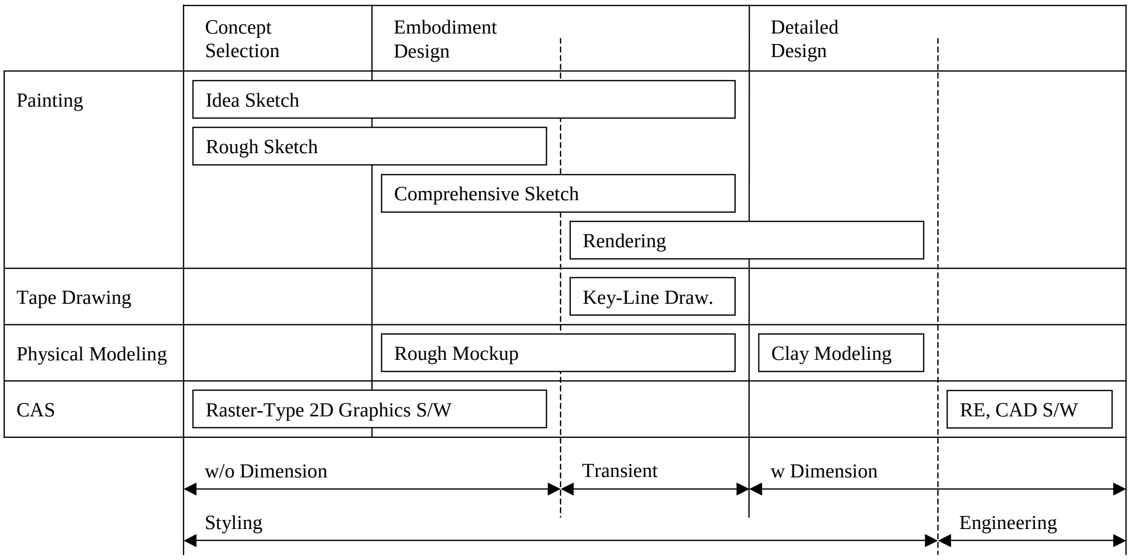


Figure 1. Current automotive styling process

2. Related Work

The research about CAS can be categorized into (1) the conversion of a traditional styling method into a digitalized form, and (2) 2D/3D evaluation of designed shapes.

A typical example of the former is the *digital tape drawing* [3], which is a kind of large-display interaction technique imitating a *physical* tape drawing. In virtue of inherent advantages of digital media, the digital tape drawing can resolve many problems that the analogue method has, such as data storage and retrieval. Grossman, et al. [9, 10] suggested integrating methods of the digital tape drawing with 3D shape modeling. A 2D curve created on the orthographic plane by using the digital tape drawing, is immediately synchronized with a 3D model. Hummels and Overbeeke [11] developed a *virtual clay modeling* tool. The designer can sketch rough surfaces in virtual space with two-handed gestures while wearing hand gloves.

One of the most important reasons of making computer models in design studios is to evaluate the 3D shape of design alternatives. As mentioned earlier, many design studios are using a power wall for substituting physical mockups with CAD models to save time and money. Tsang, et al. [17] developed a 3D annotation system, so called the *boom chameleon*, which is composed of a flat-panel display mounted to a mechanical boom. The boom chameleon shows designers a virtual image of a designed car at an arbitrary viewpoint, and enables them to discuss about design issues and to add various types of comments. Tovey and Owen [16] suggested a simple 3D model creation method for the conceptual design stage, which was based on the texture-mapping of orthographic rendering images onto a simple solid geometry.

On the other hand, lately many research teams are trying to introduce VR interfaces (or 3D interfaces) for directly creating 3D shapes. However, in spite of great potentials of VR technologies, it looks premature to apply them to the *actual* automotive styling process at the present time.

3. Characteristics of Automotive Styling Process

Because of the fairly large size of cars, the automotive styling process can be characterized with a keyword, *dimension*. In the concept design and the early phase of embodiment design stages, where diverse ideas are actively generated and hybridized until satisfactory styling concepts are concreted, the dimension is not an important factor. Whereas, in the detailed design stage, where a real-size physical model is made, the final appearance of a car is fixed, and its CAD model is generated, all the operations are done in consideration of accurate dimensions. On the other hand, the latter part of the embodiment design stage is intermediate. In this section, we will briefly deal with the characteristics of each styling step.

• *Dimensionless styling stage*

The working characteristics of the concept selection and the early embodiment design stages are: (1) the *rapid* generation of plenty of styling ideas, (2) the *flexible* hybridization of existing alternatives, and (3) the *sensuous* expression of rough shapes. Conventionally, painting techniques have been used in this stage, and recently, *raster-type* 2D graphics S/Ws such as Alias Sketchbook Pro^{TM} were introduced because of their similarity to a physical drawing.

• *Actual-dimension styling stage*

Compared with the design process for relatively small-sized products, real-size operations are much important in automotive styling because there might be severe unwanted or unpleasant defects in actual size although they do not appear on desktop displays or in scale models. Thus, the actual-dimension styling stage has consisted of two steps: (1) to make a *real-size physical model* of clay, wood, resin, form urethane, etc., for determining the final style of a car, and (2) to create a *computer model* for manufacturing purposes. Making a physical model is a special *artistic* activity based on a real-size dimension sense, while creating a computer model from the physical model is a series of *technological* operations with a high-precision measuring system and engineering-based modeling S/Ws. Lately, considerable efforts have been made on substituting physical models with computer models by reason of time and money. Already a power wall became a common tool in automotive design studios, and a CAVE system is now undergoing for a more immersive evaluation.

• *Trans-dimension styling stage*

In this stage, reference information for the actual-dimension styling stage is made based on an embodied styling alternative. One of the typical methods is a *tape drawing*, which is an extraordinary method of creating large-size drawing on upright walls. Key-line drawings by using a tape drawing act an important guide for clay modelers to reflect design concepts in a clay model.

4. Guidelines for Automotive CAS

The expected benefits from a successful digitalization of the styling process are: (1) to overcome the weaknesses of analogue methods, including difficulties of data storage/retrieval, partial modification, etc., (2) to increase the communication level between each design step, and (3) in special, for automotive styling, to allow 3D evaluation at the early design development phase.

Raster-type 2D graphics tools, which are used in the dimensionless styling stages, enable designers to express their ideas sensuously and quickly. However, because these S/Ws are basically *image-based*, they inevitably have serious problems in: (1) editing strokes, (2) storing touch history, and (3) keeping a digital connectivity with the downstream process. Sometimes, designers directly make computer models by using CAD S/Ws for checking the 3D shape of intermediate design alternatives. But, there is considerable *reluctance* because (1) CAD S/Ws restrict designers' creativity by forcing them to follow an engineering way to create 3D shapes, and (2) most CAD techniques are quite time-consuming. On the other hand, there have been a little digital techniques mimic existing shaping methods. But it is really regrettable that most of them were not companied with serious deliberations on a harmonious working flow. Needless to say, it is important to raise the efficiency of each operation itself by digitalizing the media. However, it is more important to harmonize all the operations in view of concurrent engineering. Based on these considerations in previous section and this section, we are to suggest several directions for a desirable CAS environment that can support a smooth digital styling process as follows:

- *Guideline 1*: For the dimensionless styling stage, a *vector-type* graphics S/W having an intuitive and user-friendly interface appropriate for style concept handling, should be introduced for a smooth data flow into the following styling stages. If possible, it is advisable not to use raster-type graphics S/Ws from the viewpoint of concurrent engineering.
- *Guideline 2*: In the trans-dimension styling step, a digitalized styling method should (1) be able to *import* digital data created in the previous styling step, and (2) focus on *modifying* shapes rather than re-creating.
- *Guideline 3*: The use of engineering-based CAD S/W should be avoided in the styling development process. Because the major reason of making computer models in the styling phase is for checking 3D shapes of intermediate ideas based on the designer's feeling, it is desirable to use a *styling-purposed* modeling S/W having a *quick 3D evaluation* functionality.

Shown in the upper part of Fig. 2 is a new CAS flow considering above three premises. Vector-type styling data can flow naturally down the proposed CAS stream, and consequently, the resulting automotive styling process can be more smoothly and effectively.

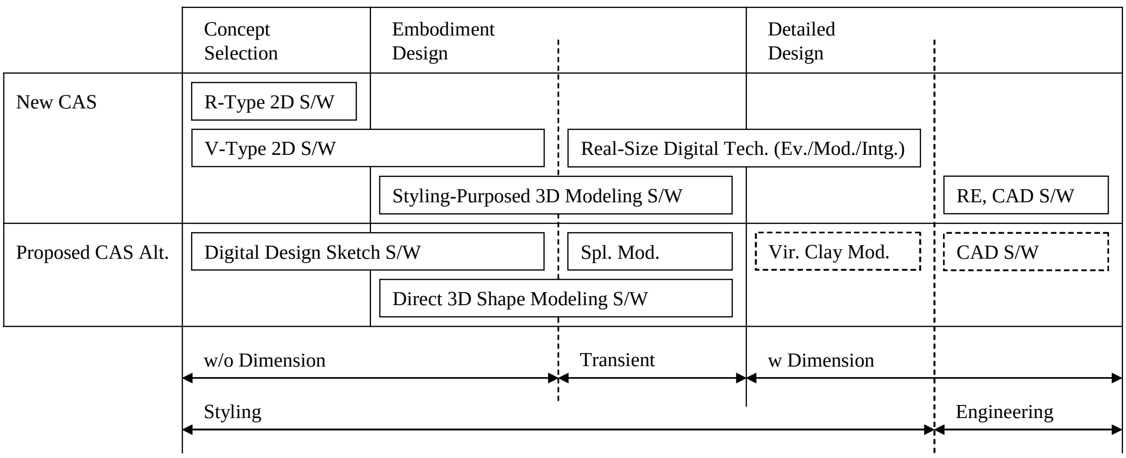


Figure 2. New CAS flow and proposed alternatives

5. Prospective CAS Alternatives

In this section, three possible alternatives, which follow the CAS guidelines proposed in the previous section, are presented (see the lower part of Fig. 2). The *digital design sketch* is a vector-type graphics S/W that provides the product designers with a great fluency of a pen-based interface. The *real-size spline modification* system, which is composed of a large-display projection system and graspable handles, can imports vector-type curve information, and modifies the large curves with a real-scale feeling. On the other hand, for an early 3D evaluation, a *direct 3D shape modeling* S/W can be used, which is based on an accurate space sense of professional automotive designers.

5.1. Digital Design Sketch

In our previous study [1], the digital design sketch was proposed. It is a digitally emulated sketching S/W based on the in-depth observation and analysis of product designers' *design sketch* behaviors and their works. As design-sketch elements, a simply-tensioned smooth curve and arbitrary rotated ellipse were singled out, and simple vector-type mathematical entities were mapped to them. The physical adaptation process of a design sketch was implemented in the computer environment while keeping its own behavioral characteristics. By using a visual drawing guide – already drawn curves *grayed* and *spread out* in order, the designers can freely and accurately express their ideas (see Fig. 3).

The digital design sketch (1) inherits most merits of a physical sketch (the simplicity of its way and equipment, the speed, and the easiness to catch ideas), (2) complements weak points (hand shaking, imperfect proportion or perspective, annoying cleaning up), (3) resolves data management problems (storage, retrieval, modification), and (4) allows the designer to easily accustom to itself because a sketching is the designer's most familiar way of not only expressing ideas but also thinking.

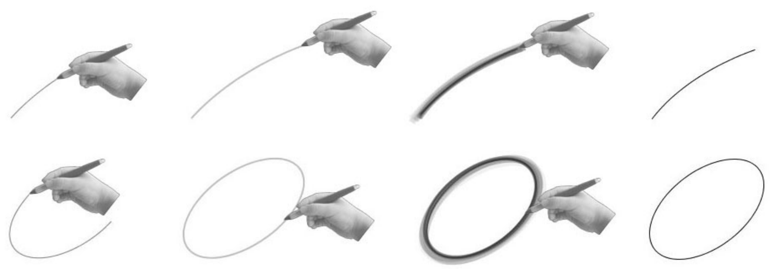


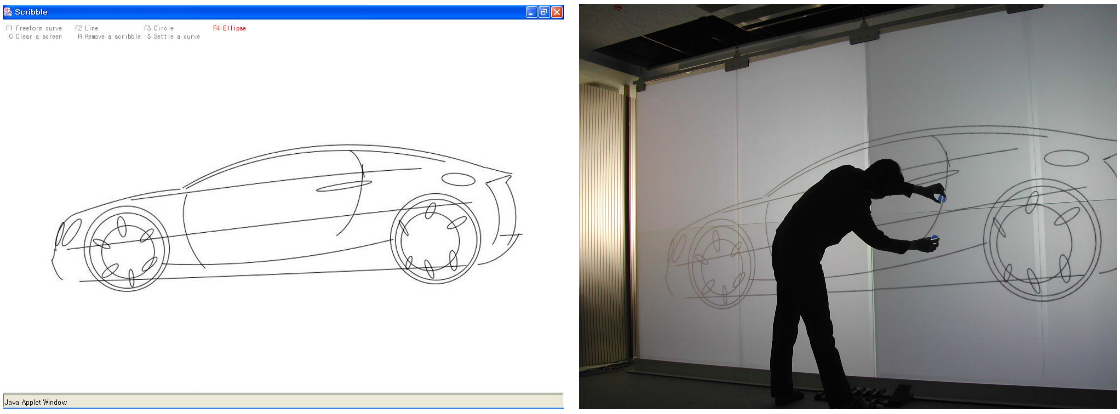
Figure 3. Digital design sketch

5.2. Real-Size Large Spline Curve Modification

A key-line drawing plays a crucial role for intercommunications among designers, modelers, and engineers because it contains a fundamental layout from orthogonal views for real-size modeling [20]. Traditionally a key-line drawing has been made by tape drawing techniques because of the vertical configuration of a drawing surface and large size of geometries (mainly curves) to be created. As large-projection display technologies are highly matured, even small paintings can be shown scaled up on a big screen. In other words, now, it is not necessary to directly create key lines in real size. Thus, it is more advisable to concentrate on *fine-tuning* of the geometry of large-size curves with a real-size feeling rather than re-creating a big layout in the trans-dimension styling stage, under the assumption that a vector-type graphics S/W is used in the upstream process.

Shown in Fig 4 are (a) a sketch drawn by using the digital design sketch S/W and (b) real-size spline curve modification system, with which the designer is modifying large key curves in an interactive manner. Because the digital design sketch S/W can export DDS files in which all the geometric entities are written as NURBS, the designer, by importing a DDS file, can directly modify the curves with the interactive modifying system without creating the curves again.

Basic ideas of our system for modifying large-size spline curves are: (1) to combine *graspable handles* [8] with a *perceptual wall* configuration [7, 19, 14, 18], and (2) to develop a *gestural interface* compatible with spline curve manipulation. The developed system has many advantages compared with not only an existing analogue technique, but also CRT-based spline curve modification. The designer can (1) use DDS files as the starting point of creating key-line drawing, (2) refer additional geometric information such as the curvature of a curve, (3) impose special constraints due to manufacturing or related laws and regulations, (4) undo and redo the previous operations, and so forth. Furthermore, the performance of modification can highly increase in virtue of its two-handed modification manner [12] (compare with CRT-based methods in which generally one-handed interface is adopted) and multi-user collaboration. Also, there is a great possibility to integrate 2D styling with 3D styling by introducing a bi-directional 2D/3D update scheme.



(a) (b)

Figure 4. (a) Sketch by digital design sketch S/W and (b) real-size large spline curve modification system

5.3. Direct 3D Shape Creation with Perspective 3D Sketch

There has been much research about directly creating 3D computer models by using a sketch interface, and most of the studies have focused on (1) the primitive shape recognition, and (2) the topology reconstruction, from an inaccurate sketch of a mechanical part [21, 6, 13, 15]. However, for a 3D evaluation in automotive styling, the situation is slightly different because we can assume that well-trained automotive stylists can express 3D shapes on a 2D plane based on *design perspective* [5]. It is not an exaggeration that the professional product designer has a quite accurate *human* 3D-graphics rendering pipeline. Furthermore, a fact that all the automobiles (except of little *avant-garde* style) have *plane symmetric* shapes, makes it (relatively) easier for the designer to create exact perspective drawings.

Bae, et al. [2] suggested a method to create 3D plane-symmetric freeform curves with the *perspective 3D sketch* that is straightforwardly extended from the (2D) digital design sketch. Although the inverse-projection problem finding a 3D object from its 2D image onto an arbitrary plane, is under-determined problem having an infinite numbers of solutions, it is possible to obtain an *unique* 3D freeform curve from a 2D curve drawn by the designer in virtue of a strong reconstruction hint, a *plane symmetry* (there exist a little special viewing-conditions under which the method does not work. See the original paper [2] for more details).

The direct creation method of 3D freeform curves proposed by Bae, et al. can be simply extended to that of a *four-sided* freeform surface in 3D space. Now we are developing a direct 3D evaluation system for automotive styling by applying this method so that the designer can create a rough 3D base model from a rendering image with it as shown in Fig. 5 (the original source of the underlying image is http://www.autoshow21.com).

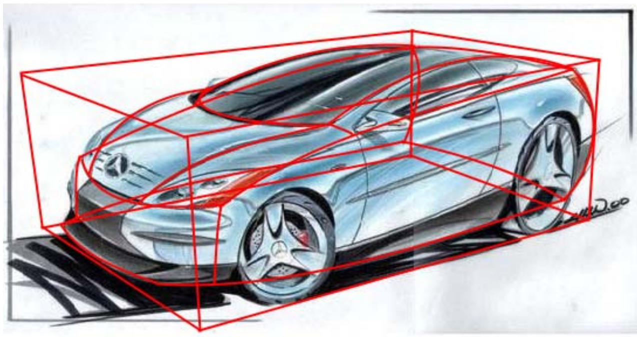


Figure 5. Simple 3D model creation for concept design

6. Discussions and Conclusions

In this paper, for a more effective and harmonious automotive styling process, three CAS guidelines were proposed: (1) to use the graphics S/Ws based on a vector-type data handling scheme in the dimensionless styling stage, (2) to focus on modification rather than re-creation in the trans-dimension styling stage, and (3) to avoid using engineering-based CAD S/Ws in the styling development process. The guidelines resulted from the observation and analysis of the characteristics of the current automotive styling process, and laid special emphasis on concurrent engineering as well as the improvement of each individual styling operation. Also, this paper suggested three prospective CAS systems obeying the proposed guidelines: (1) the digital design sketch S/W, (2) real-size large spline curve modification system composed of a perceptual wall and graspable handles, and (3) direct 3D shape creation S/W with the perspective 3D sketch. Although the above three alternatives can not cover the whole styling process at present, they will fill important roles of making the automotive styling process more tightly organized as other CAS methods – compatible with the proposed guidelines – appear by ones.

In establishing a digital environment for automotive designers, the most important thing is to try to find technical solutions that can maximize the designer's ability. First of all, there should be efforts to fully comprehend the designer's way to understand and express shapes. The designer's artistic activities must be re-interpreted in mathematical (or engineering) languages. Then, they can be finally realized in the digital form follows the proper CAS guidelines. As a matter of course, it is inevitable that a successful digitalization of automotive styling can be accomplished by close cooperation between designers and engineers (or system developers).

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