

Design Appearance Evaluation Tool for Non-prototype Development

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ABSTRACT

The aim with this paper is to achieve a tool for non-prototype automotive development that is faster, simpler, and enables judgment equivalent to that with a physical model. Evaluation by the computer graphics to convey the appeal of shapes by means of artistic effects is commonly used. In non-prototype development, computer graphic output effects allowing the same judgment as with a physical model are required, and this approach has to yield output for evaluation with highly accurate results and by a realistic amount of calculation time without depending on the skills of individuals.

The computer graphic software named Total Objective and Physical Simulation was developed in order to achieve the required computer graphic output with a reasonable amount of calculation time. It was decided that the software would not use manual adjustment of environment and material parameters, but instead handle only data measured from actual objects. In addition, Monte Carlo path tracing specialized for parallel Graphic Processing Units was adopted for the calculation technique. This tool achieved physically correct rendering based on measurement data with a high level of performance.

1. Introduction

There are at present increasing requirements for non-prototype approaches to automobile development in order to shorten development time.

In the design field, mockups are fabricated and evaluated in order to judge styling design quality. However the judgment of styling design quality at the final stages leading to mass production requires to confirm the accurate appearance that includes the functional components involved. This is referred to as design appearance evaluation. Design appearance evaluation needs judgment of a prototype car, and taking into consideration the process until completion of a prototype car, it poses a major issue for the shortening of development time.

This development will describe the features and results from workplace use of the computer graphics (CG) software known as Total Objective and Physical Simulation (TOPS), which has been under development to enable CG confirmation as an alternative to the prototype car in design appearance evaluation.

2. Development Goals

2.1. Differences from Conventional CG Software

Conventionally, the role of CG software in design development was mainly in the area of concept design

in the initial stages of development. This area calls for effective rendering of the appeal of the design concept and shape intended by the designers. In many cases, therefore, this would convey the appeal of the shape by depicting it in ways that are not to be found in reality, as seen in Fig. 1(a). Consequently, these images are modified by tuning in many ways. Specialized personnel with advanced CG skills are also needed to implement the tuning.

However, in order for the appeal intended by the designers to be carried over into mass production, not only the appeal of the shape, but also the appearance when fabricated as a physical model need to be confirmed. Conventionally, this was done using mockups and prototype cars. In non-prototype development, however, a final check using a physical model cannot be performed, and so this needs to be done using CG. For this kind of confirmation, the output should not be the kind of presentation in Fig. 1(a), should accurately depict the physical model as though in a photograph, in Fig. 1(b). In addition, enabling judgment equal to that of a physical model should not depend on skills, should keep consistent uniformity. Software that satisfied this requirement did not exist, and so it was decided to develop new software.

2.2. Requirements for Design Appearance Evaluation

Conventionally, design appearance evaluation was implemented with imagery data processed using CATIA,

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and this method clarify brought numerous issues. On many of the points identified, however, judgment cannot be readily made on the basis of imagery data, and many points require a physical model in order to make a judgment. Consequently, confirmation is made in combination with the use of a prototype car. The identified items were therefore analyzed, and they were found to be subject to tendency classification as shown in Fig. 2.

Particular items tending to require an actual vehicle to enable judgment were found to be summarized as (1) glass reflections and refractions, (2) reflections matching the material and appearance of the internal looks through gaps, and (3) shade on fit and gap areas (Fig. 3). These areas revealed conspicuous differences in appearance between CATIA and an actual vehicle, so that proper design appearance evaluation could not be readily performed. These points in particular, therefore, require rendering that presents their appearance accurately.

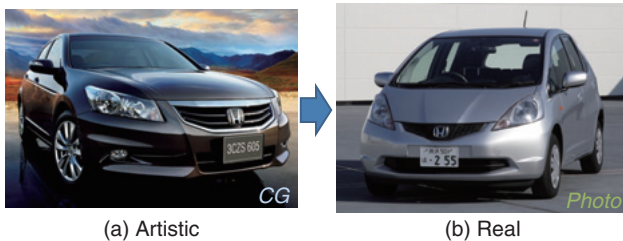


Fig. 1 Artistic and Real

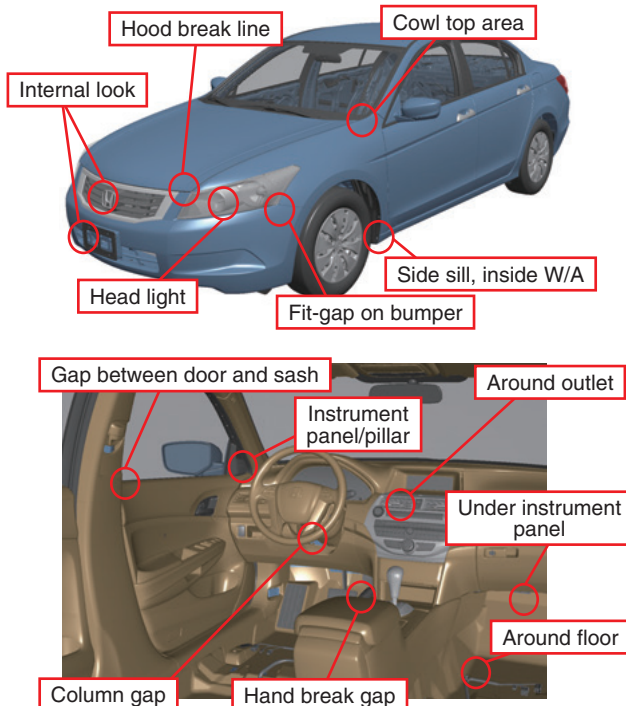


Fig. 2 Issues reported as “Physical model required”

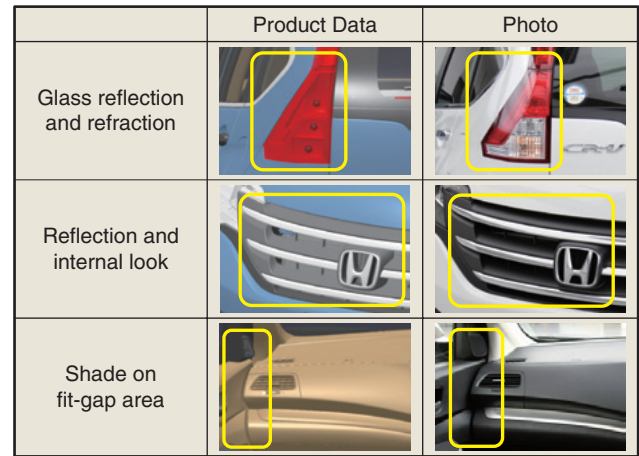


Fig. 3 Points of attention for physical model check

3. Technology to Achieve Goals

3.1. Technical Issues

In order to use technological means to achieve the desired requirements, accurate simulations of light and material objects are needed. This, first of all, needs accurate shape data on the vehicle. It additionally needs an environment model that is accurately rendered in the same way as an actual space, and a material model that accurately renders surface characteristics in the same way as a physical model.

Simulation of light behavior is performed using the above three (Fig. 4), but since this entails a massive amount of calculation, conventional CG software uses many arbitrary approximation methods to obtain its results. In order to render the physical model, however, it is necessary to eliminate arbitrary approximation processing and to perform accurate calculation in detail. Considering also that this is being used in the automotive development workplace, a system that outputs results interactively in response to user operations is sought. It is also necessary to

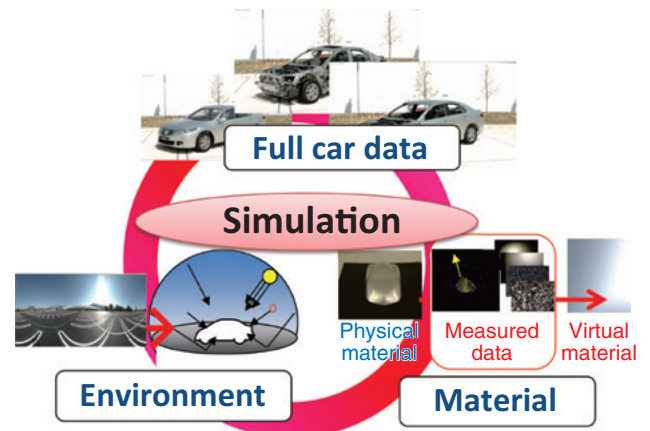


Fig. 4 TOPS overall structure

produce results within a short calculating time, even if the calculations are massive.

To summarize, the technical issues needing to be overcome were (1) technology for rendering material properties, (2) technology for rendering environment characteristics, and (3) computing technology for completing the processing quickly.

3.2. Technology for Rendering Material Properties

Three technologies were used to render material properties: a measuring instrument for obtaining the reflection characteristics (Bidirectional Reflectance Distribution Function: BRDF)⁽¹⁾ for all angles of incidence and reflection angles; a microscope for measuring minute light behavior of flakes and so on included in coatings; and a highly accurate scanner for measuring surface texture and other large patterns. The BRDF in particular is an important element in representing material properties. However, commercial measuring instruments do not readily provide accurate measurement data for certain areas, such as in a regular reflection direction and at angles close to the horizontal.

The physical properties were therefore obtained from coated surfaces, plastic, glass, and other such compositions, and matching material models were created. As regards elements of importance for material properties, such as materials, processing methods, and so on, information was available on those materials that are used within Honda, and this allowed the formation of models specialized for the use of those materials. This enables compensation for measuring instrument error and accurate material rendering (Fig. 5).

3.3. Technology for Rendering Environment Characteristics

Measurement of the environment needs accurate measurement of light intensity and hue. For that purpose, a camera that captures High Dynamic Range (HDR) imagery containing more color information than ordinary imagery was used together with an actinometer that measures absolute values of light intensity. In addition, gamma value

correction and white balance correction matched to the camera characteristics were performed, and an environment model with well-adjusted light intensity and color balance was created (Fig. 6).

3.4. Computing Technology

The method adopted for calculation of the simulation is called Path Tracing⁽²⁾, which performs light calculations all together without approximations. This method does not separate the categories of direct light and indirect light. The calculations of light from the environment falling on material objects are performed all together.

In high-precision CG software, a method called Ray Tracing⁽³⁾ is often used. This performs calculations only of direct light, which can be done at greater speed. This method alone is unable to render shadows accurately, so it is used together with a variety of methods known as Global Illumination^{(4), (5)} that handle indirect light, which involves enormous amounts of calculation, by rendering approximations. This can render an appearance that is similar to that produced by indirect light calculation. However, the rendering requires large amounts of manual tuning, which has a major influence on the output results.

In Path Tracing, by contrast, indirect light is also calculated as part of the whole so that indirect light can be rendered accurately and manual tuning is not needed (Fig. 7). The amount of calculation becomes massive, however, and in order to achieve higher calculation speed, TOPS focused on the GPU, which has shown rapidly increasing performance in recent years.

GPU is generally a processing unit that is specialized for graphics processing. Compared to a central processing unit (CPU), which is commonly used to calculate simulations, the GPU enables fast calculations at lower cost. However, the GPU is not well suited to branch processing and other such more complex calculations, and achieving high calculating capability has to involve simplification and

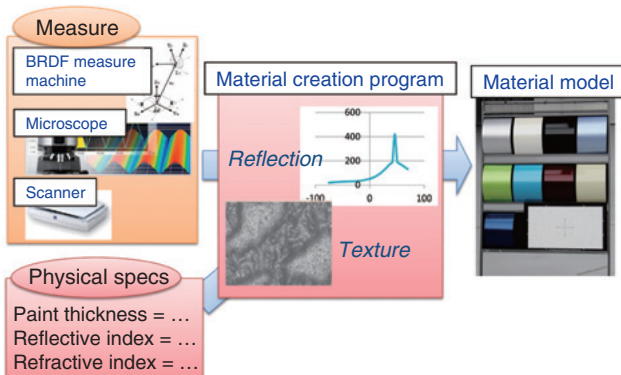


Fig. 5 TOPS material creation

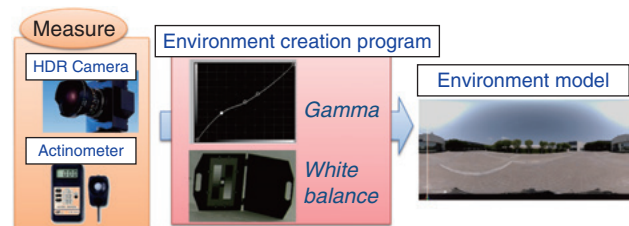


Fig. 6 TOPS environment creation

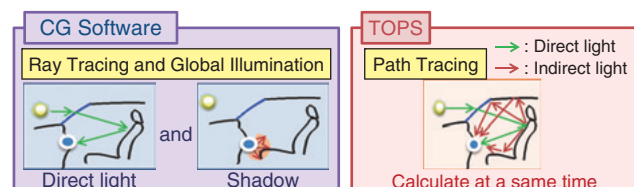


Fig. 7 TOPS rendering engine

parallelization of individual calculations.

The Monte Carlo method, which performs simulations in a probabilistic manner, was therefore adopted for TOPS, and it was implemented to employ parallel processing specialized for the GPU. The Monte Carlo method performs repeated calculations using random numbers, and each calculation is independent. This makes it more readily adaptable to parallelization, and suits this method to calculation using a GPU.

4. Results

Figures 8 and 9 show actual vehicle photographs and TOPS output results. The actual vehicle photographs also indicate points of attention for design appearance evaluation. All the environment and material information was created from measured data, and these results achieve rendering with an appearance identical to photographs.

These results can be considered to yield output on a par with photographs with regard to the visual points that need confirmation using an actual vehicle. The openings and inside of the wheel house in Fig. 8 appear to be lighter than on the actual vehicle. This is because the fin shapes, surface processing, and other details of functional components inside the openings are areas that were not included in

the drawing issue data, so they were not reflected in the rendering data and they therefore present a different appearance. In order to obtain a more accurate appearance, therefore, more accurate shape rendering is necessary.

Figure 10 shows TOPS output results for different materials. Since differences in material have a large impact

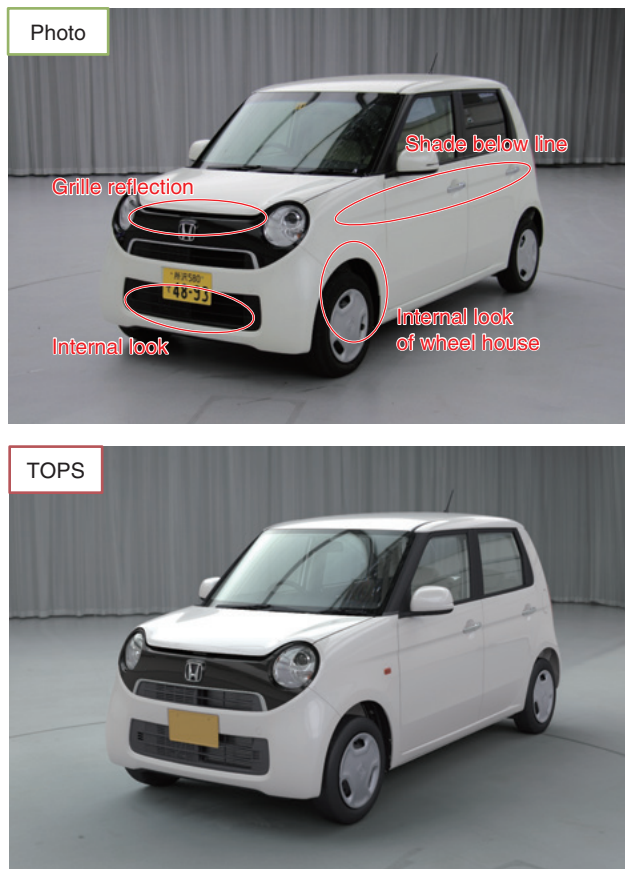


Fig. 8 TOPS result (Exterior)

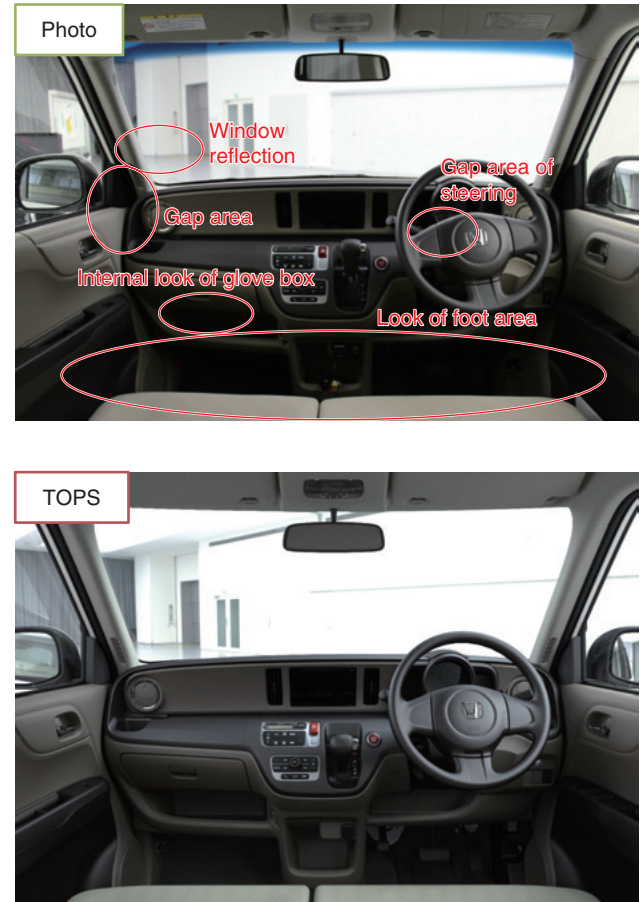


Fig. 9 TOPS result (Interior)



Fig. 10 TOPS result (Appearance difference by material)

on the appearance, TOPS calculates the various material properties and renders the way highlights and shadows appear according to the material.

Next, regarding calculation time, TOPS maximizes use of an arrangement specialized for the GPU by mounting eight high-performance GPUs (seven NVIDIA Tesla K10 chips and one NVIDIA Tesla M2070Q) in a single computer.

Calculation time increases according to how many times reflection and refraction phenomena appear. Consequently, the vehicle lights that involve calculation of appearance seen through more complex lenses are the parts that take the most calculation time. Figure 11 shows the results from rendering the lights in Full HD (1920×1080) resolution. The Monte Carlo method initially yields results that contain considerable noise, but then these gradually resolve. The result after 0.1 second is extremely noisy, but after five seconds the image generally resolves. Stable results are obtained in about 60 seconds.

Even in those areas that take the most time, therefore, approximate results can be obtained in about five seconds. This can be considered to have achieved sufficient calculation speed to enable interactive operation.

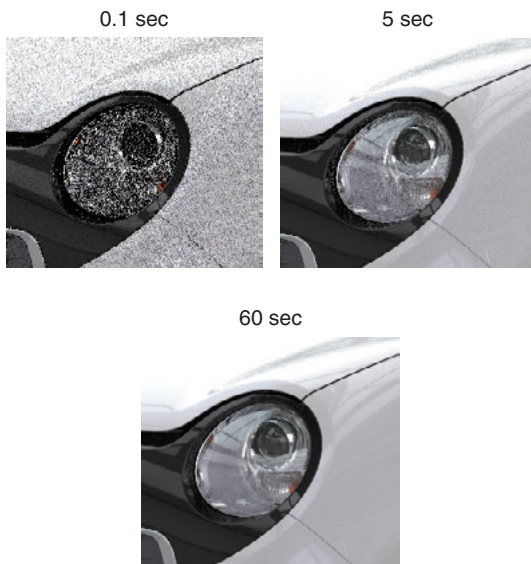


Fig. 11 TOPS result (Performance)

5. Conclusion and Future Outlook

In moving toward non-prototype development, development of TOPS has been pursued with the aim of achieving design appearance evaluation by CG that is equivalent to use of a physical model. TOPS differs from conventional CG software in that it creates all the data for rendering environment and material from measured data, and in that it calculates accurate simulations of light at

high speed. This was able to produce rendering results that are equivalent to use of a physical model. This approach achieved a degree of accuracy in rendering data that is adequate for design appearance evaluation of items that, until now, could only be checked using a prototype car.

However, the appearance equivalent to a photograph that was achieved here cannot be considered equal to the appearance of a physical model in actual human eyes. Human eyes automatically apply compensation to input information, and they can see things that are not visible in a photograph.

Figure 12 shows photographs that are all taken of actual cars. In the case of photographs, when they are taken so that the darker areas are visible, the lighter areas are washed out, and when they are taken so the lighter areas are visible, the darker areas turn all black. To the actual human eye, however, both seem to be visible simultaneously. The use of CG to render an image for judgment that can completely replace the physical model in design appearance evaluation will depend on consideration of rendering methods that are faithful to reality and that can adequately reproduce the effects of the human eye.

Advanced rendering methods will be necessary in order to move forward from photographic quality to physical model quality. First, it is necessary to obtain real-time calculation performance to capture shapes dynamically. Since the TOPS calculation method can be readily parallelized, it achieves higher levels of scalability with respect to hardware enhancement, and it is capable of reaching that next step.

Second, it is necessary to enhance display devices. The present effort used standard display devices with Full HD resolution and 24-bit color resolution, but devices with still more advanced resolution and color resolution have been coming on the market. Higher color resolution can be considered particularly effective in enhancing reproducibility. In addition, the use of calibration matched to the display device can be expected to render output that is identical to the actual appearance of the space being viewed.

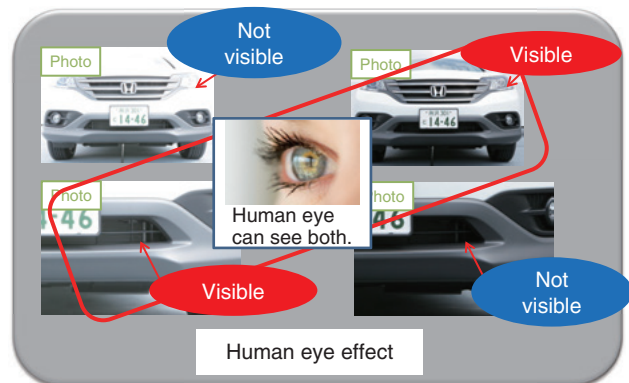


Fig. 12 Photo realistic and real

Third, Rendering of three-dimensional space will also be necessary. That will require highly accurate 3D display devices that can render an accurate sense of distance, so future evolutions of technology will be explored.

In conjunction with that, verification of the correlation with the actual vehicle will be performed repeatedly by comparing actual vehicles side by side with TOPS output in order to confirm whether output equal to the physical model is being obtained. This will investigate human evaluation methods and uncover requirements.

Our intention is to continue pursuing further development and deployment in order to build systems that will contribute to non-prototype development.

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