

Coordination of Information between Design and Manufacture Domains by 3D Annotated Model

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ABSTRACT

In order to maintain product quality while shortening development time, it is necessary to conduct front-loaded development. This involves digital verification conducted at an early stage of development using a 3D model of the vehicle instead of working with an actual vehicle.

What can become bottlenecks in this process are drawings that have design information presented in 2D form. Therefore, a consistent process utilizing 3D from design to manufacturing was built, taking as its core the conversion of design information to a 3D annotated model (3DA), which consists of drawings that aggregate all that information in 3D form. A notable point about the adoption of 3DA is the degree of freedom it provides for storage methods and data structure of the shape elements and attributes possessed by 3DA, according to the particular characteristics of the drawings, so as to enable smooth coordination between divisions and systems.

By these means, the early verification of 3D data using 3DA and the enhancement of efficiency in 3DA drawing creation were realized.

1. Introduction

Automobile development in recent years has had to shorten development time while maintaining vehicle quality in order to provide a high-quality product in a timely manner. As this occurs, it is becoming increasingly commonplace to consider and verify product specifications using 3D data in every stage from design to manufacture.

The drawings that show the product shapes for stamped body parts and other such elements (parts drawings) have the product shapes in the form of 3D data. The manufacturing divisions work with those drawings in verification and manufacture of the products. In contrast, there are drawings that show instructions for joining products to each other, sealing them, assembling them, and the like. These are the illustration drawings, whose purpose is combining the product shapes into the finished product. The locations of joins, the areas for coating sealing, and other instructions are also maintained in the form of 3D data during the stage of consideration in the design offices, where their feasibility is examined. When this data was converted into conventional illustration

drawings, however, the items of 3D data were projected into 2D drawings, with the design instruction information that was relevant to the purpose of the illustration drawings then added to the 2D drawings in the form of annotations.

Consequently, those in the manufacturing divisions who are responsible for using the illustration drawings would look at the 2D drawings and read the information from them. They would then perform the following operations as necessary.

- (1) Create 3D shapes for use in robot teaching
- (2) Transfer the design instructions into the form of the respective manufacturing manuals
- (3) Consider specifications that envision the way the parts are utilized in the actual car

The issues that arise in the above operations include the labor required to read, transfer, and create the data, as well as the possibility of human error during transfer. Regarding operation (3), above, since it could be performed more easily through confirmation on an actual car, this operation could only be carried out when an actual car existed, from the middle stages of development

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onward. Due to issues such as these, verification using only 2D drawings was time-consuming, and verification of specifications in the manufacturing divisions at an early stage by means of illustration drawings only took place in some of the divisions.

In light of the fact that the design offices make use of 3D data at early stages of the development process, it was determined that, by converting illustration drawings into 3D annotated models (hereafter, 3DA) and creating a consistent process for utilization of 3D data, digital verification could be carried out efficiently using highly accurate 3D data equivalent to the use of an actual car at early stages of development before there is an actual car.

This article introduces the structure of 3DA and its effects.

2. The Aim of Conversion to 3DA

The use of 3DA in product model development had the following three main aims:

- (1) To create processes for utilizing 3D data by converting illustration drawings to 3DA;
- (2) To carry out early verification using 3DA illustration drawings; and
- (3) To enhance the efficiency of the process of creating 3DA illustration drawings.

The 3D+2D drawing format that used to be the primary method in use would represent shapes using 3D data, and record attributes on 2D drawings in the form of design instruction information. When making the conversion to 3DA, the 3D data and the attributes had to be integrated efficiently in the form of 3D data, which then had to be seamlessly linked to subsequent processes. It was necessary to consider drawing formats that could be handled efficiently in such a way that, whether the 3D data or the attributes were edited, no mismatching would occur.

As shown in Fig. 1, therefore, design instruction information (marked with ※ in the figure) is stored inside the 3D data as attributes and treated as parameters. This reduces mismatching between design intentions and annotations, and controls the stored attribute information, which enables greater efficiency in drawing creation and utilization of drawings.

As shown in Fig. 2, those responsible for making use of illustration drawings through utilization of conventional 2D drawings formerly made suppositions about the specifications as they conducted their examination. This resulted in inconsistent accuracy, and did not lead to early consideration. The measures introduced here provide for free storage of attributes and enabling of control so that the 3D data can be used in all processes and coordination can seamlessly take place. This enabled the creation of processes for the consistent utilization of 3D data.

The use of 3D data to convert drawings to 3DA further allows actions to coordinate utilization between divisions

and systems in ways that could not have been managed with conventional drawings.

When converting illustration drawings to 3DA, the ways in which drawings were being used were sorted out. The usage items that were thus identified were assigned to new processes that use 3D data, and structures for retaining 3D data and locations for storing design instructions in 3D data in the form of attributes were defined in order to make the processes operative.

When designers stored the design instructions by the conventional method for creating drawings, manually entering the design instructions as text required labor. Moreover, this process involved repetitive work, and therefore tended to result in human error. With the conversion to 3DA, however, systems that allow for automated entry of 3D data were developed, and this enhanced the efficiency of design work and the accuracy of design instruction entry.

Carrying out these measures achieved the aims numbered (1) to (3) enumerated at the beginning of this section.

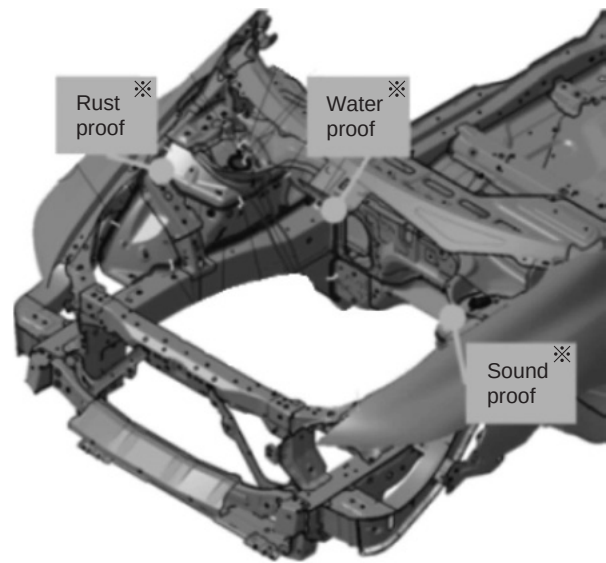


Fig. 1 Keeping attributes in 3D

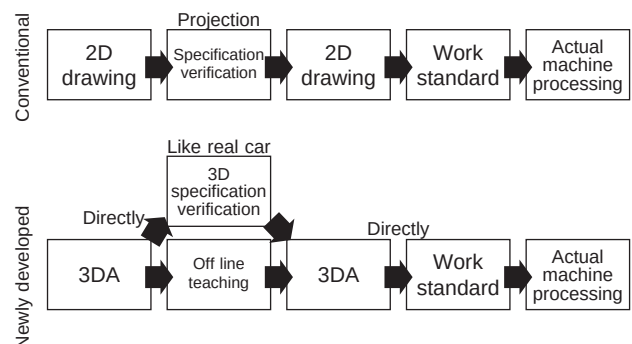


Fig. 2 3D process

3. Basic 3DA Structure

The following explains the basic 3DA structure.

Specific points to observe in creating 3DA drawings in order to conduct smooth coordination between divisions and systems include:

- (1) Classification of shape elements;
- (2) Method for storage of attributes; and
- (3) Structure of the data.

Establishing the above three items to allow a degree of freedom with respect to each particular characteristic of a drawing can enable a variety of different uses, as described in the next section.

3.1. Classification of Shape Elements

Shape elements are classified, as shown in Table 1, into product shape and supplementary shape.

The product shapes that belong in 3DA should be 3D data that enable digital verification close to that with an actual car. Examples include body shapes like those shown in Fig. 3 and shapes of combination elements like those shown in Fig. 4.

Supplementary shapes should be 3D data that are in accordance with the product shape and in a form suitable for use in simulations, manufacturing, and the like. Examples include the centerline that indicates normal direction such as shown in Fig. 5 and the edge curve (marked with ※ in the figure) such as shown in Fig. 6.

3.2. Method for Storage of Attributes

The method for storage of attributes was devised to enable the use, as needed, of the attributes shown in Table 2. These are attributes that reflect drawing information and design instructions (design attributes) and

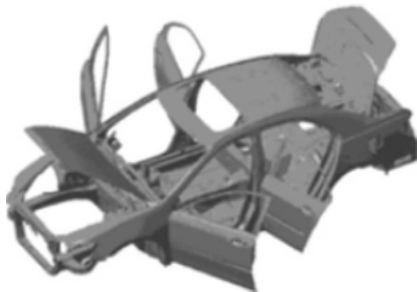


Fig. 3 Body shape

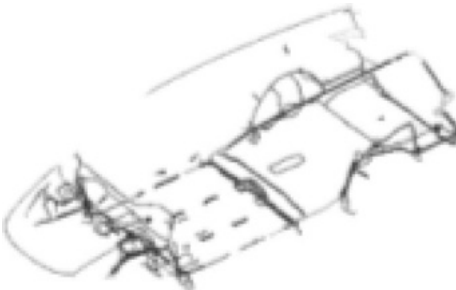


Fig. 4 Shape of combination element

Table 1 Shape element

Shape element	3D shape
Product shape	Body shape, Shape of combination element (adhesives, sealer, MIG weld, etc...), Indication symbol ...
Supplementary shape	Center point, Centerline, Center curve, Edge curve, Area surface ...

Table 2 Attribute list

Attribute	Example
Design attribute	Part number, Part name, Length, Tolerance, Angle, Surface roughness, Mass, Variation, Material, Thickness, Position, Normal direction, Destination ...
System attribute	Management number, System ID, Sequential number, Flag, ...

attributes that serve as identification for the system (system attributes).

A system that automatically acquires 3D data information (part numbers and other such attributes that are already present in the 3D data) and stores it as attributes of design instructions can also be developed in order to enhance the efficiency of drawing creation. By means of a system such as that shown in Fig. 7, designers

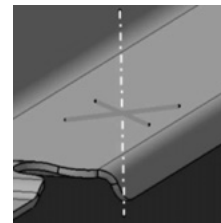


Fig. 5 Centerline

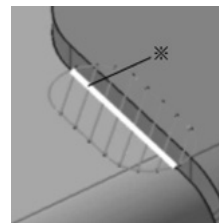


Fig. 6 Edge curve

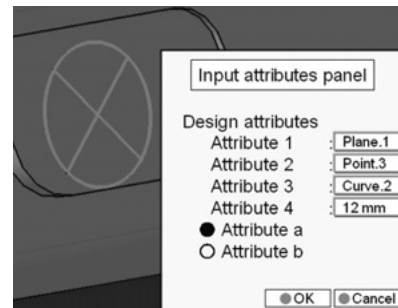


Fig. 7 Input attributes on 3D

will be able, during the course of drawing creation, to store the attributes of design instructions in storage locations controlled by system attributes without having to consider those locations.

3.3. Data Structure

The use of 3DA requires that 3D data be stored in a data structure such as that in Fig. 8. This involves putting the various shape elements and attributes discussed above into systematic order and storing them in 3D data according to defined naming rules. This enables the system to output and display drawing information in accordance with the rules for a well-ordered data structure.

In order to observe the data structure rules when creating data for a design, it is necessary to have files of drawing templates to serve as a base for the 3DA data structure. A system to enable automatic sorting and ordering of the data is also required.

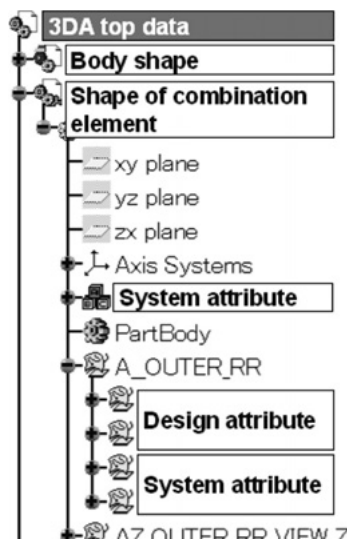


Fig. 8 Data structure

4. Case Examples of 3DA Use

With the aim of front-loading development, 3DA were created at design offices and consistent processes for the use of 3D data in the manufacturing divisions were developed. It was stated in the first section that the following operations would be performed for the purpose of smooth coordination between divisions and systems. Case examples of the use of such operations will be given.

- (1) Create 3D shapes for use in robot teaching
- (2) Transfer the design instructions into the form of the respective manufacturing manuals
- (3) Consider specifications that envision the way the parts are utilized in the actual car

4.1. Use in Robot Teaching

Supplementary shapes are included in 3DA out of

consideration for system coordination with subsequent processes. The center curve, which is a supplementary shape, was included within the 3DA as shown in Fig. 9 so that it could be used as a guide for the robot teaching path.

4.2. Use in Manufacturing Manuals

The method devised for storing design instruction information in the form of attributes realized coordination with a manufacturing manual as described in the following.

In order to make use of the information or to store it at the manufacturing site under the conventional system, those responsible for it in the manufacturing divisions should copy it from the 2D drawings to something resembling a manufacturing manual that they create on paper media. Accelerating conversion to 3DA has created sudden increases in demand for use of 3D data, making it necessary to output the groups of information stored as attributes in the 3D data onto a paper medium in order to create a manufacturing manual. With 3DA, the input and output of attributes is controlled and storage methods are devised whereby that information can be freely used. As a result, the information can be exported in a variety of formats.

As shown in Fig. 10, the system attributes included

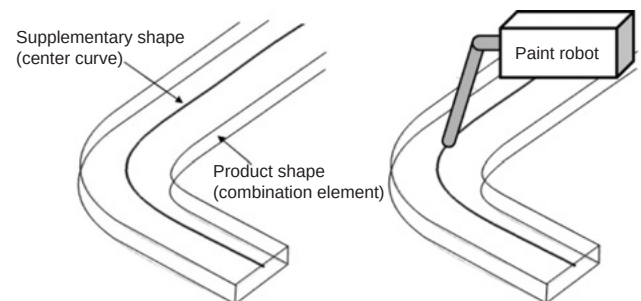


Fig. 9 Utilization of supplementary shape

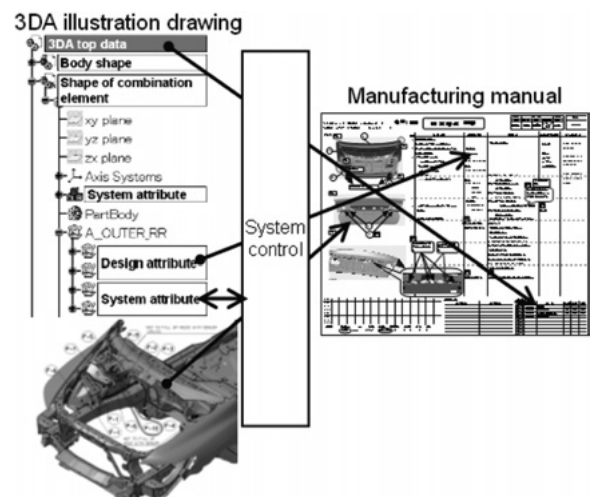


Fig. 10 Utilization of system attributes

in 3DA illustration drawings can be used as keys for automatic control by the system of attributes that are stored in accordance with the data structure rules. The necessary information can be output as PC data in Excel or another such format. Due to the automatic creation of manufacturing manuals from 3DA, transcription errors have been excluded from the creation process and the labor required has been reduced.

4.3. Use in Specification Verification

Those shapes that are necessary for each particular process in the manufacturing divisions can be isolated from the configuration of the bill of material and extracted for provision where needed. In this way, the data structure can be made to link seamlessly with the verification of each process. Where the conventional approach employed verification by projection, those items of data and the design instructions within the 3DA are combined to realize a digital verification that is equivalent to verification using an actual car.

As shown in Fig. 11, the consideration of locations for coating sealer formerly involved the estimation of joining areas from conventional 2D drawings. With the conversion to 3DA, however, joining areas can be confirmed from 3D data that is close to that from an actual car. Moreover, including shapes as design instructions has enabled consideration with greater precision in the manufacturing divisions.

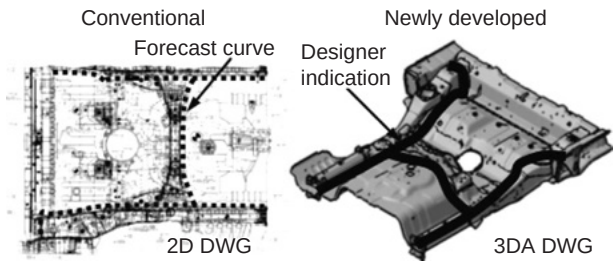


Fig. 11 Utilization of data structure

5. Effects of Conversion to 3DA

Practical implementation of the aims and measures described above realized the creation of consistent processes for utilizing 3D data. This enabled early verification of 3D data using 3DA illustration drawings and enhancement of efficiency in 3DA illustration drawing creation.

Figure 12 shows variations in the number of reports from the manufacturing divisions at each development stage regarding issues with illustration drawings. With a conventional model under development (Car-A in the figure), there were more reports of issues in the middle stage of development. With a model to which processes

utilizing 3DA were applied (Car-B in the figure), verification at an early stage of development enabled reports to be made one event in advance of issues that used to be discovered later. Deeply rooted issues can therefore be addressed earlier.

The necessary processes can be created by implementing related measures in parallel and combining the various measures, realizing verification at an early stage of development. This makes it necessary to issue 3DA illustration drawings early, and the key to this is achieving higher efficiency in creation of drawings in the design offices.

Enhanced efficiency in the creation of 3DA illustration drawings requires reevaluation directed primarily at the issues involved in conventional 2D drawing, the content of repetitive tasks, and the like.

Figure 13 shows an example of heightened efficiency in drawing creation. When creating conventional 2D drawings, the views marked 3, 4, and 5 in the upper part of the figure are created, design instructions are added in the form of annotations, and sections are created. These tasks are carried out repeatedly so that they make up a

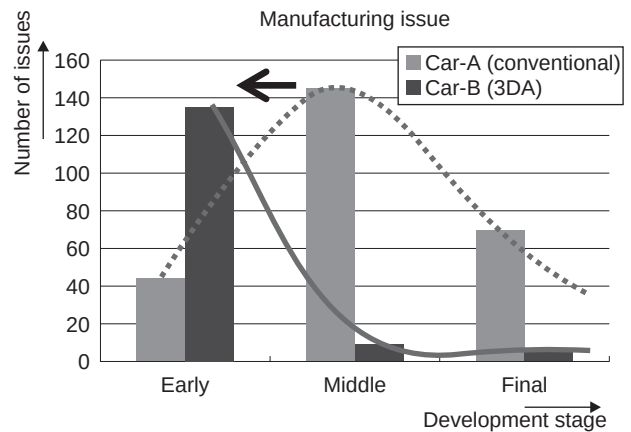


Fig. 12 Number of issues identified by manufacturing domain

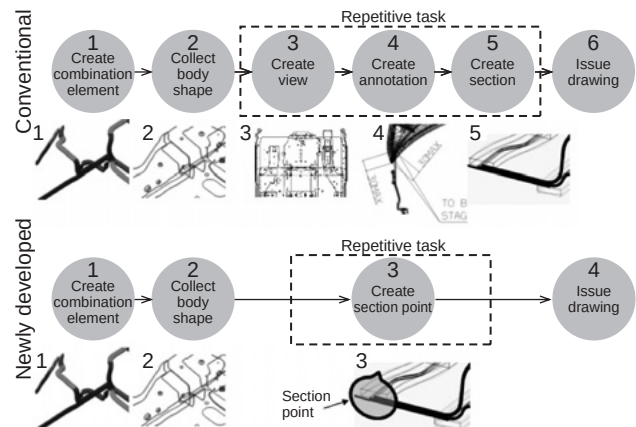


Fig. 13 Enhancing process of making drawings

large proportion of the total labor of drawing creation. When creating 3DA drawings, those tasks are replaced by the sole task of storing attributes at section points as shown in view 3 in the lower part of the figure. Thus, the work became easier and the labor required to create drawings was reduced.

The enhancements made in usability together with the creation of a work process that is free of overloads and inefficiency can realize a reduction in the labor required to create drawings without sacrificing former levels of quality.

6. Conclusion

Illustration drawings were converted to 3DA in order to create consistent processes for utilizing 3D data. This enabled the use of highly accurate 3D data to perform digital verification equivalent to that performed using an actual car at the early stages of development before there is an actual car.

The important point in converting to 3DA is not the replacement of conventional drawings with new ones. Rather, it is necessary to analyze the vehicle development process in order to clearly identify duplicated jobs, repetitive tasks, transfer work and other such bottlenecks. The process can then be recreated in an optimized form that resolves those issues. In doing so, a data structure is adopted that allows free input and output of the attributes, support by CAD functions is added so that the design offices and manufacturing divisions can handle the attributes more easily, and drawings that match the recreated processes should be made.

These measures were adopted and consequently realized front-loading with heightened efficiency in drawing creation and easier coordination of information in design and manufacturing.

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