

Development of Technology to Create Surfaces with High-speed from Measurement Data

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ABSTRACT

Transformation of measurement data from parts into CAD models allows the data to be more widely used in the automotive development process. Surfaces are formulated from the data and fed back into the CAD model. These surfaces must correlate well with a low degree of error against the measurement data.

However, creating these surfaces requires considerable data processing time. A new algorithm for surface creation that combines high accuracy with high-speed processing has therefore been developed. This has resulted in a 90% reduction in the time required for surface creation with no significant increase in error.

1. Introduction

Two-dimensional (2-D) blueprints and three-dimensional (3-D) shape data have become common design tools in automobile development in recent years. As non-contact measurement tools have evolved, it has become possible to measure the dimensions listed on 2D blueprints (diameters, heights, etc.) as well as 3D surface forms, and the amount of information available has increased dramatically.

Transforming measurement data into surfaces and using it in CAD systems, where all automobile development starts, allows developers to use this increased amount of information (data), offering the following potential benefits.

- (1) Verification by 3D layout
Even products for which blueprints and CAD data do not exist can be verified by 3D layout.
- (2) CAM-based cutting programs
Cutting programs can be written for the form data derived from the products, making it possible to take the form of the product into account when machining it.
- (3) Edited forms reflected in design values
Product forms that workers have revised can easily be reflected in design values.

- (4) CAE analysis using measurement data

Form data for actual articles can be transformed into CAD data and undergo CAE analyses, enabling a functional comparison of design values and actual articles.

The ability to create surfaces that differ only slightly from measurement data is essential to reaping these benefits, and ordinarily it is accepted that this error should be within ± 0.1 mm.

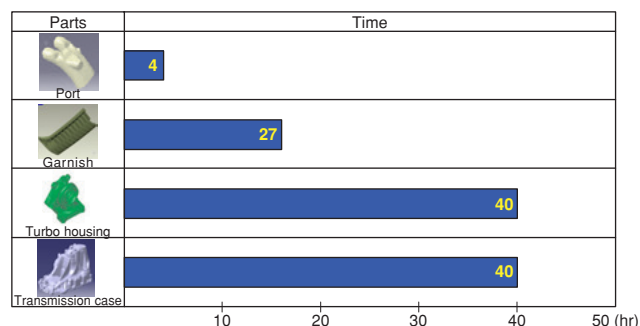


Fig. 1 Time required for creation of surfaces before software development

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However, keeping error within ± 0.1 mm when the measured form is complicated requires a great deal of time, particularly for components like transmission cases (Fig. 1), and this becomes an issue in the use of measurement data.

This article provides details on a newly developed algorithm for creating surfaces with the following two target values.

- (1) Error within ± 0.1 mm of measurement data for the surface created
- (2) Time required to create surfaces reduced by 90%

2. Current State of Surface Creation

2.1. Clarification of Processes Needing Modification

The process of creating surfaces from measurement data goes as follows.

- Measurement data editing
- Display of polygonal form
- Polygon editing
- Surface layout editing
- Creation of surface

First, to clarify the areas of the surface creation process that need modification, standard data (for a transmission case) was used to verify the time needed for each process (Fig. 2).

The results indicated that two of the five processes, (3) polygon editing and (4) surface layout editing, had a significant impact on surface creation time.

2.1.1. Polygon editing

Faults occur in triangular polygons created using the measurement data's 3D coordinates as apexes. The forms represented by these polygons do not adequately capture measurement data and the surface status of the product (especially glossiness) is inadequate for the measurement (Fig. 3). The objective of this process was to make up for these polygon faults and achieve smooth, continuous forms.

With the standard data, 308 polygon faults were confirmed. Selecting and editing each of these manually required 14 hours.

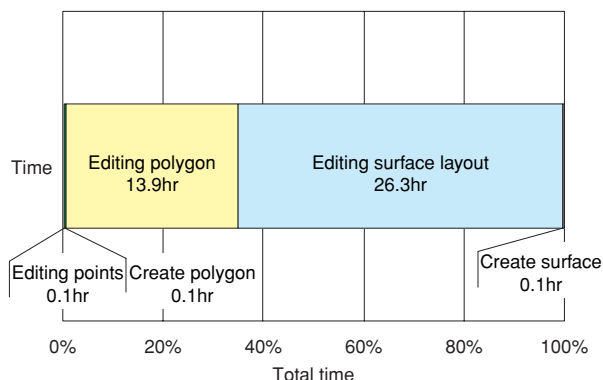


Fig. 2 Time required for each process in creation of surface

2.1.2. Surface layout editing

Details of this process (Fig. 4) are given below.

- (1) The curvature distribution of the form represented by polygons is calculated and contour lines are automatically created.
- (2) At the discretion of the operator, contour lines other than edges are manually edited to follow points of inflection.
- (3) To produce surfaces within the areas bounded by the contour lines, the regions (below, "patches") separated by the four sides are automatically created.
- (4) The arrangement of each patch is manually edited to minimize the changes in curvature within the patch.

These processes are performed to minimize the error between measurement data and the surface created, and also to minimize the size (i.e. the bytes) of the data.

To track the changes in curvature, and thereby minimize deviation from the measurement data, the number of points used to determine surface form must be increased. (These are known as control points.) However, the surface's control points increase in units of one column and one row, so that the data capacity increases proportionately to about the square of the number of control points (Fig. 5), which has an impact on the processing time of the various data. Results of verifying this process with the standard data indicated that the process took 26 hours.

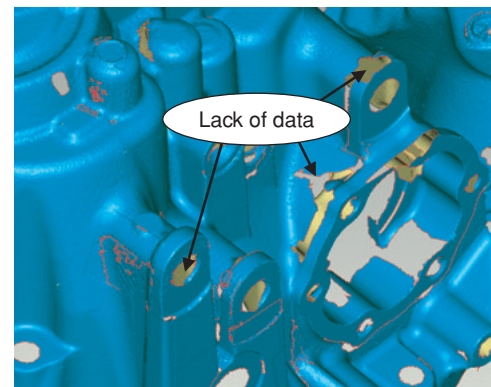


Fig. 3 Hole caused by lack of data

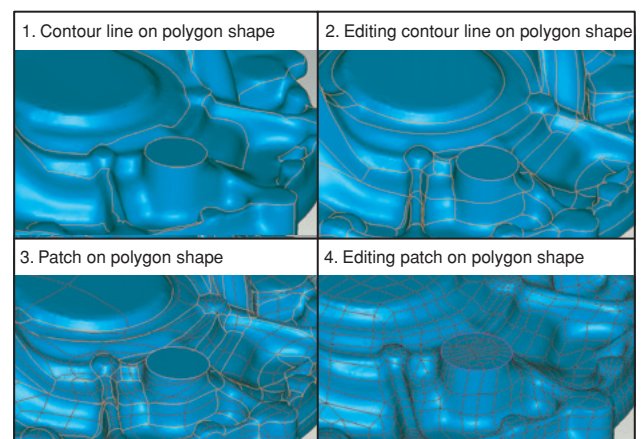


Fig. 4 Generation process of patch lay-out

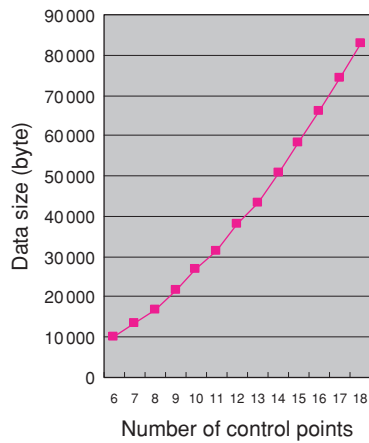


Fig. 5 Relation of control points and data size

3. New Technique

One factor common to these two processes, which increases the time it takes to create a surface, is a need for manual editing. Therefore the authors devised a technique that focuses on how to make manual tasks more efficient.

3.1. Polygon Editing

In this process operators have had to manually select and edit, one at a time, multiple areas with data faults where the shape or size differs. The authors felt that to solve this problem, ideally the operator would have to be able to edit multiple areas simultaneously and that it was important to be able to efficiently select areas where the same editing technique could be used. They devised the following technique based on those ideas.

3.1.1. Selecting parts to edit

In the new technique, the operator can define the conditions for selecting parts to edit and thereby select only polygon fault areas containing forms that meet those conditions. The conditions determine the form characteristics of the fault areas and include such factors as the number of polygon sides facing the fault area, the circumference of the fault area and the flatness of the outline of the fault area. Combining and defining such conditions enables the operator to select fault areas with the same characteristics and edit them all at once.

The defined conditions, moreover, can be saved in a file and used again to edit other measurement data polygons.

3.2. Surface Layout Editing

Until now, contour lines and patches that were automatically detected have been manually edited because the process sought to strike a balance between data capacity on the one hand, and deviations between the created surface and measurement data on the other. The authors have devised a new algorithm that enables efficient manual editing.

3.2.1. Creating contour lines

Creating contour lines has been very time-consuming because the operator has had to perform editing to follow points of inflection and parts found to be edges. To begin, curvature changes for the overall form, represented by the polygon, were calculated to find areas with significant curvature (Fig. 6), and contour lines were created to pass through the centers of these areas (Fig. 7). The operator is able to increase the number of contour lines as necessary.

3.2.2. Creating patches

Considering data size (bytes) and error between measured form and the surface created, it is preferable if the measurement form encompassed by one patch does not have significant curvature change when that patch is created. For that reason, when creating contour lines, patches are created with the contour lines as boundaries on polygons found to have significant curvature (Fig. 8), then patches are created in areas where the remaining curvature change is small. This means that within a single patch, there is no significant curvature change.

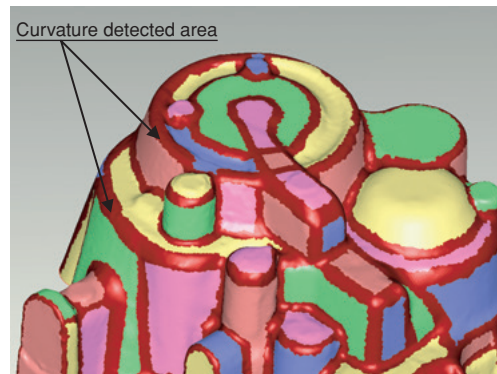


Fig. 6 Discrimination curvature

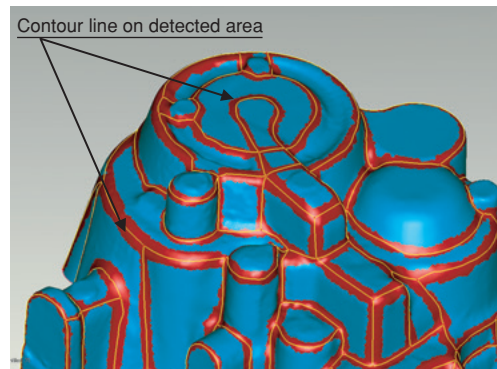


Fig. 7 Contour line created on areas of discrimination curvature

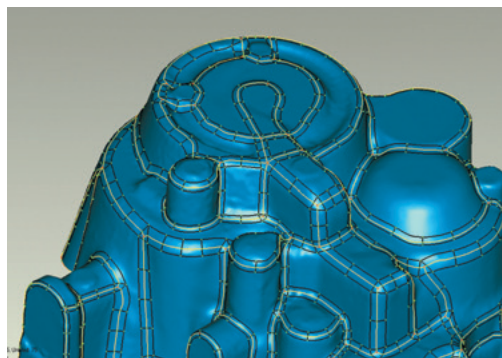


Fig. 8 Patch created on areas of greater curvature

4. Effectiveness

Applying the new algorithm to the existing processes had the following results: When using standard data, the time needed to edit polygons dropped from 14 hours to 1.2 hours and the time required for surface layout editing dropped from 26 hours to 2.6 hours. For all processes, the time it took to create a surface dropped from 40 hours to 3.8 hours. This meets the established target of reducing processing time using standard data by 90% (Fig. 9). Results of verification with other components showed that the time needed to create surfaces declined by 80% or more (Fig. 10) and that it has become possible to shorten the processing time while maintaining the precision of the surface created.

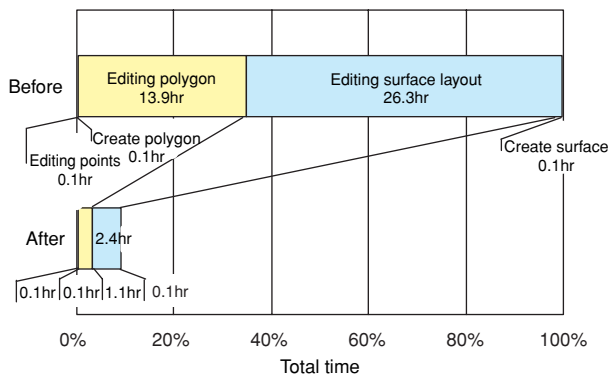


Fig. 9 Time required for each process in creation of surface before and after software development

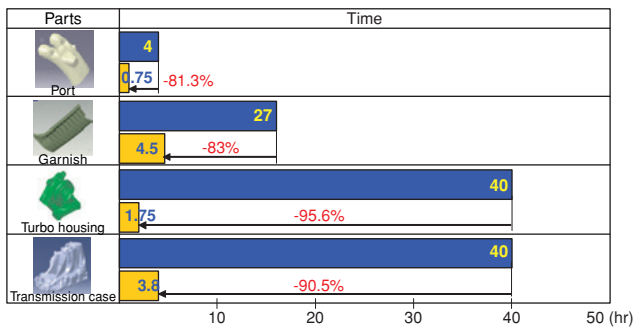


Fig. 10 Verification results of time for creation of surfaces

5. Conclusion

The authors have developed a new algorithm for surface creation that combines high accuracy with high-speed processing from product data.

- (1) Using condition definitions, to select in bulk polygon areas that need revision, enables the operator to reduce the time spent manually selecting areas to edit.
- (2) Curvature changes are calculated and contour lines are created from the areas found. These are the main areas with significant curvature from which patches are created. This enables the operator to reduce the time spent editing contour lines in arbitrary areas.

6. Afterword

The newly devised algorithm makes it possible to shorten the time needed to supply data and also makes it possible to supply data in a timely manner on demand, even when dealing with complicated forms like transmission cases.

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