Study on Improving Accuracy for Edge Measurement Using 3D Laser Scanner

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Abstract. A high accuracy edge measurement method of edges of components using point cloud data by 3D laser scanner is proposed in this paper. The proposed method consists of two parts: method for shape measurement of edges by using points of side faces of the components and method for length measurement of edges by attaching the 3D targets. At the experiments with a surface plate and a curved shell plate, the results give suggestions for having possibility of applying this proposed method for actual shipbuilding components.

Keywords: Laser Scanner, Point Cloud Data, Edge Measurement, 3D Target.

1 Introduction

At different manufacturing sites, accurate measurement of large components is of vital importance.

For example, at each manufacturing stage of shipbuilding process, the shapes and sizes of the ship's components are measured and the accuracy is evaluated to reduce the cost of the rework in subsequent manufacturing stages including welding process specifically. Different 3D measurement system is employed for accuracy evaluation of components. Kim et al. suggested the 3D virtual simulation method of shipbuilding blocks using 3D measurement data by total station [1]. According to Shibahara et al., a method of 3D welding deformation measurement based on stereo imaging technique was developed [2].

Because most of the ship's components are very large, it is efficient to conduct measurement by using 3D laser scanner which can measures the whole surface of components at one time as one set of point cloud data. An edge measurement method for shipbuilding blocks was developed [3]. In this existing method, the points of edges are directly extracted from point cloud data based on the distance from a floor panel of the shipbuilding block. However, it is difficult to obtain the accurate shape and the length of edges from the measured point cloud due to intervals existing even in high density point cloud data of the large component.

In this study, a high accuracy edge measurement method of components using 3D laser scanner is proposed. Concretely, the method for edge's shape measurement using the point cloud of the component's side face and the method for edge's length measurement using the feature points of the 3D targets are explained.

S. Fukuda et al. (Eds.): PLM 2014, IFIP AICT 442, pp. 427–434, 2014.

2 Proposed Method

2.1 Overview

Fig. 1 illustrates the overview of the proposed method. The proposed method consists of two parts: method for shape measurement of edges by using points of side faces of the components and method for length measurement of edges by attaching the 3D targets.

In the method for shape measurement of edges, first of all, the component is measured by 3D laser scanner and the point cloud data including the surface part and side faces of the component are obtained. The continuous surface part is extracted using region growing method. To shorten the calculating time, the point cloud data of the surface part is thinned and the points of the thinned points cloud data's boundaries are detected. Using the detected boundary points, the points of the side faces are recognized and plane fitting is carried out locally to-ward the recognized points. Finally, the points on the edges are calculated according to the surface part and the fitted side face planes.

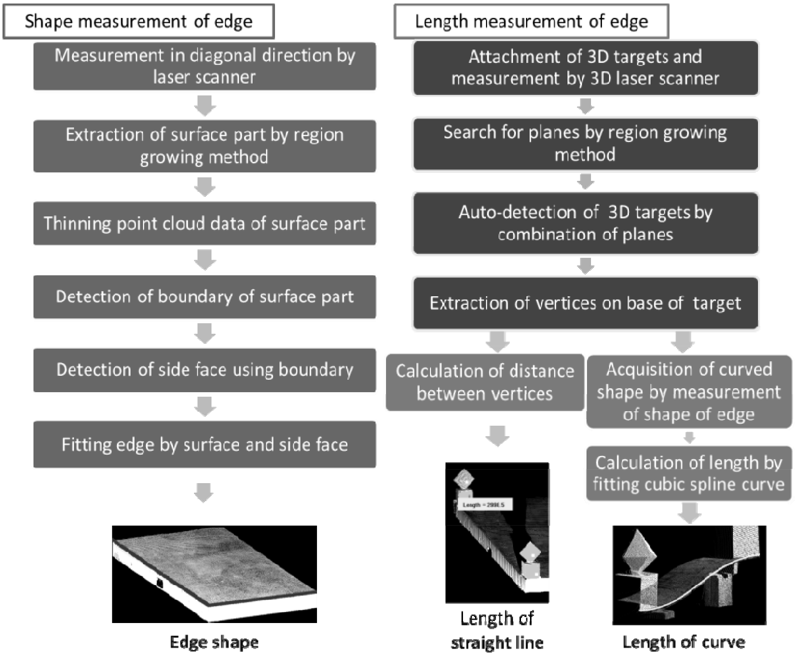

Fig. 1. Overview of the proposed method

In the method for length measurement of edges, at first the 3D targets, whose upper side is regular octahedron and the lower side is cube, are attached on the corners of the component and the component is measured by 3D laser scanner. Firstly, planar domains are detected from the obtained point cloud data and the position and direction information of the targets are recognized by the proper combination of the detected planes. Then, the vertices representing the edge's endpoints on the base of the targets are extracted. If the shape of the edge is a straight line, the length of the edge is calculated by calculating the distance be-tween the vertices. On the other hand, if the shape is curve, the shape is acquired by the shape measurement method of edges mentioned above and the length is calculated by fitting a cubic spline curve toward the calculated edge points.

2.2 Edge's Shape Measurement Method

First, the component is measured by 3D laser scanner and point cloud data including the surface part and the side faces of the component are obtained. An arbitrary point on the surface of the component is selected from the measured data and only the points of surface part are extracted by region growing method [4]. The point cloud except for the extracted surface part including the component's side face is detected at following process.

In order to reduce computational complexity in the following process, the point cloud of the surface part is thinned. The concrete procedure of thinning is described following.

1. Principal component of the surface part is analyzed and it is divided into two equal parts by a plane which is vertical to the first principal component vector.
2. The operation 1 is repeated for the other divided parts until the number of points from each separated part becomes less than a fixed threshold.
3. A set of each part's gravity center is considered as thinned points of the surface part.

Next, the points on the boundary are detected from the thinned point cloud of the surface using edge detecting method from Kalogerakis [5].

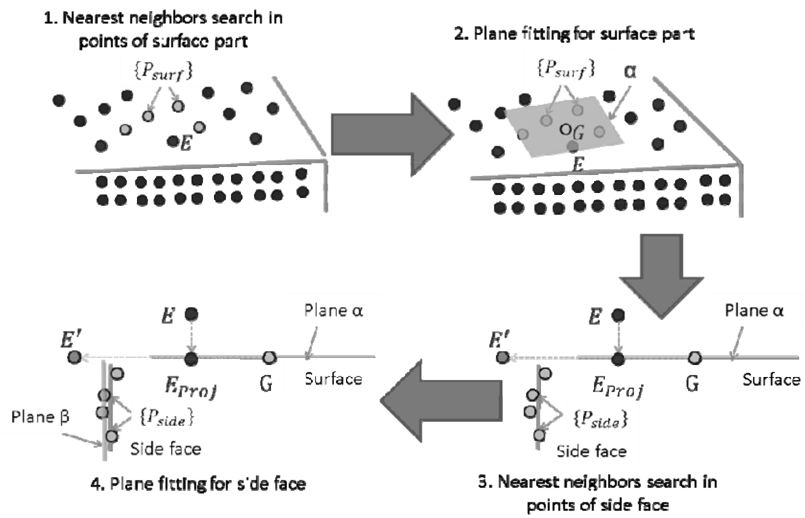

Fig. 2. Procedure of edge fitting

Using the points on boundary (**E**), the shape of edges is acquired. Fig. 2 illustrates how points of edges are fitted. The procedure of edge fitting is described as following.

1. The neighborhood of **E** ($\{\boldsymbol{P}_{surf}\}$) is searched by k-NN BBF method [6] from the point cloud of the surface part.

2. The gravity center of $\{\boldsymbol{P}_{surf}\}$ (**G**) is calculated and an approximate plane α is fitted to $\{\boldsymbol{P}_{surf}\}$.
3. The projection point of **E** to plane α ($\mathbf{E}_{proj}$) is calculated. The line segment $\mathrm{GE}_{\mathrm{proj}}$ is extended toward $\mathbf{E}_{\mathrm{proj}}$ and a point on the line ($\mathbf{E}'$) is obtained. The neighborhood of $\mathbf{E}'$ ($\{\boldsymbol{P}_{side}\}$) is searched from the points except the surface in the same way as step 1.
4. An approximate plane β is fitted to $\{\boldsymbol{P}_{side}\}$ and the intersection of the line GE' and plane β is calculated. It is one of the points describing the edge.

The above procedure is conducted for each point on the boundary and the shape of the edge is obtained.

2.3 Edge's Length Measurement Method

First of all, the 3D targets are attached on the corners of the component and measured by a 3D laser scanner. The 3D target is developed by UNICUS Co., Ltd. Fig. 3 illustrates how to attach the 3D targets on the component. The 3D target consists of a regular octahedron and a cube as shown in Fig. 3. They are attached on the corners of the component and a vertex of the target is made to match a corner of the component exactly as shown in the left image of Fig. 3. The component and targets are measured from a certain direction where at least four plane surfaces of the octahedron part and one plane surface of the cube part can be obtained.

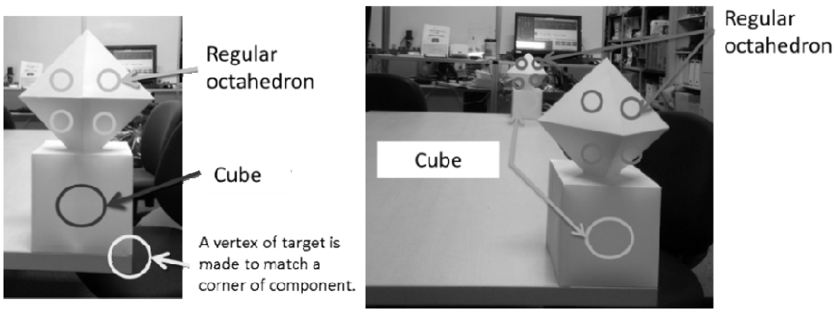

Fig. 3. Attachment of the 3D targets

Here the measured point cloud data is divided into continuous planar domains using region growing method [4]. A seed point for region growing is chosen randomly from the point cloud and all of the planes are recognized one by one.

The position and posture of the targets are recognized by doing proper combination of these recognized planes. Combination of four plane surfaces of octahedron part and one of cube part is found automatically and a target's position can be found uniquely. From the known size of 3D targets, the relative coordinates of the vertices on the base of targets is calculated.

If the shape of the edge is a straight line, the length of the edge is measured by calculating the distance between the selected two vertices of targets representing the corner of the component as shown in the left image of Fig. 4. Otherwise, if the shape of the edge is a curved line, the shape is obtained by the edge's shape measurement method introduced in section 2.2. A cubic spline curve is formed from two selected vertices of targets and the acquired points which describe the shape of the edge. An example of formed cubic spline curve is shown as a white line in the right image of Fig. 4. The edge's length is calculated from the obtained curve.

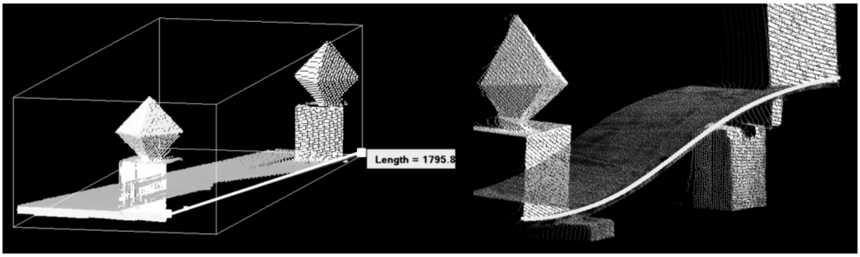

Fig. 4. Calculation of edge length

3 Experiment

Two experiments were performed to validate these proposed methods. The objective of the experiment with the measurement of a surface plate is to confirm the accuracy of measurement by the proposed method. The experiment using the curved shell plate measurement is performed to validate this proposed method with an actual sample of shipbuilding components.

In this study, the experiments are carried out by a FARO Focus3D laser scanner. Its specifications are shown in Table 1.

Table 1. Specifications of FARO Focus3D [7]

Vertical field of view (vertical/horizontal)	305° / 360°
Range	0.6 – 120m
Measurement speed	122,000 – 976,000 points/sec
Ranging error	±2mm@25m
Wavelength	905nm
Beam diamiter at exit	3.0mm

3.1 Edge Measurement of the Surface Plate

As an experiment in a laboratory environment, a surface plate was measured by 3D laser scanner. The surface plate is illustrated in the left image of Fig. 5. The plate and a laser scanner were located as shown in the right side of Fig. 5.

First, the shape of edges was measured by the method proposed in section 2.2. In this measurement, a steel plate was erected along the edge 3 to measure the edges 1, 2 and 3 at the same time as shown in the right image of Fig. 5. Fig. 6 illustrates the measured edge shape. The top image of Fig. 6 shows the whole edge shape and the bottom does an enlarged view of the framed part in the top. This shows that the points describing edges by the proposed method are obtained on the intersection of the surface and side face exactly. The error of distance between the edges 1 and 3 was -1.68mm compared with the measured value with a tape measure.

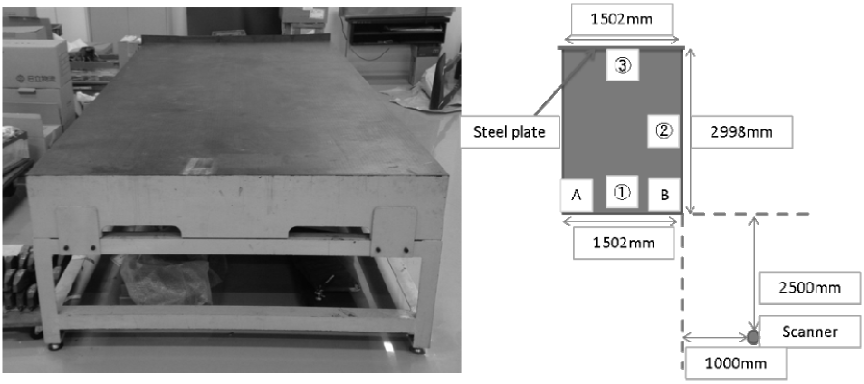

Fig. 5. Measured surface plate and arrangement of objects

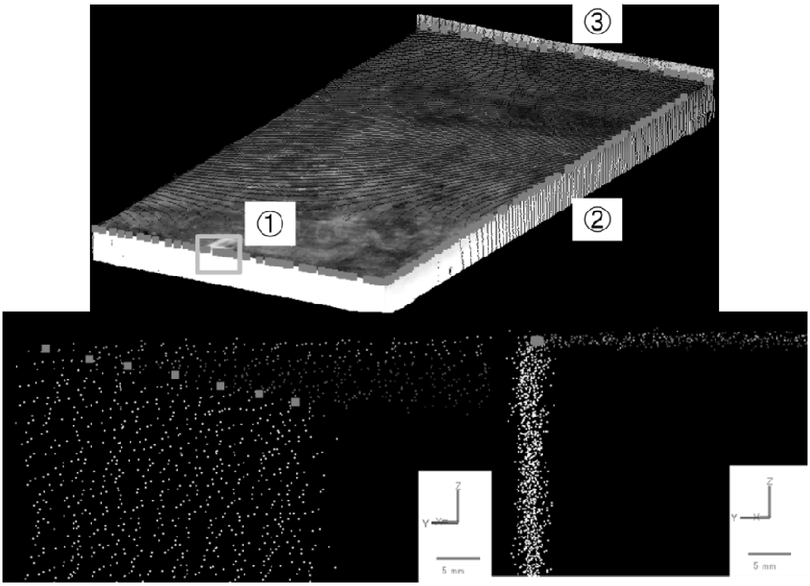

Fig. 6. Result of measurement of edge shape in an experiment with a surface plate

Table 2. Result of measurement of edge length in an experiment with a surface plate

Average value by proposed method	Standard deviation	Value by tape measure	Average of error
1501.85	0.56	1502.0	-0.15

Second, a length of an edge was measured by the method proposed in section 2.3. Two 3D targets A and B were attached on corners of the surface plate as shown in the left side of Fig. 5. The length of the edge 1 was calculated ten times. The result is shown in Table 2. The average of error is -0.15mm compared with the measured value by tape measure and standard deviation is 0.56mm. Two-sigma range is included from -1.27mm to 0.97mm. The accuracy of the error of length measured by the proposed method is less than 2mm.

3.2 Edge Measurement of the Curved Shell Plate

A curved shell plate of ship as shown in the left of Fig. 7 was measured by the proposed method. Its size by tape measure is illustrated in the right picture of Fig. 7. In this case study, the bottom edge of the plate in Fig. 7 was measured.

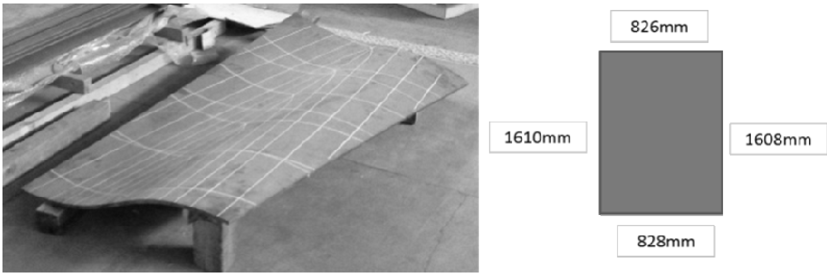

Fig. 7. Measured curved shell plate and its size

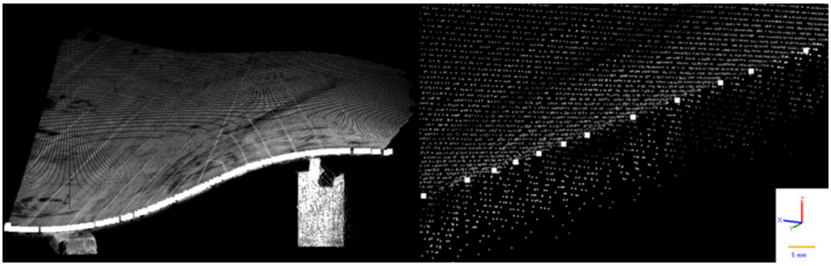

Fig. 8. Result of measurement of edge shape in an experiment with a curved shell plate

The result of measurement of edge shape by the method of section 2.2 is shown in Fig. 8. It is confirmed that the obtained white points describing the shape of the edge are in the correct position visually. The length of the same edge was calculated by the method of section 2.3. The error compared with measured value by tape measure was 0.89mm.

4 Discussion

It is necessary to manufacture shipbuilding components with less than 5mm error and detection of the error is required by measurement. In the experiment, the shape and length of edges were measured with less than 2mm error by the proposed method. Improvement in accuracy of edge measurement is achieved by using the points of the component's side face in measurement of shape and the feature points of the 3D target in measurement of length. It is considered that the error of measurement by the proposed method is small enough to evaluate accuracy of manufactured shipbuilding components such as curved shell plate.

In this study, measurement was performed only in a part of edges. There is a possibility of measuring all the shape and length of edges at one time by applying the proposed method to point cloud data obtained by registration of some data scanned from different directions.

5 Conclusion

A high accuracy edge measurement method of components using 3D laser scanner is proposed. Specifically, the method for edge's shape measurement by fitting planes to surface part and side face part of the component locally, and the method for edge's length measurement by using extracted vertices of the 3D targets attached on the component are developed. At the experiment with a surface plate, the shape and length were measured by the proposed method and the results indicated that the error was less than 2mm. At the measurement of a curved shell plate, the results give suggestions for having possibility of applying this proposed method for actual shipbuilding components.

Acknowledgments. UNICUS Co., Ltd. gives us technical supports for employing point cloud data processing platform "Pupulpit". The authors would like to thank that.

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