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Efficient point cloud data processing in shipbuilding: Reformative component extraction method and registration method

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Abstract

To survive in the current shipbuilding industry, it is of vital importance for shipyards to have the ship components' accuracy evaluated efficiently during most of the manufacturing steps. Evaluating components' accuracy by comparing each component's point cloud data scanned by laser scanners and the ship's design data formatted in CAD cannot be processed efficiently when (1) extract components from point cloud data include irregular obstacles endogenously, or when (2) registration of the two data sets have no clear direction setting. This paper presents reformative point cloud data processing methods to solve these problems. K-d tree construction of the point cloud data fastens a neighbor searching of each point. Region growing method performed on the neighbor points of the seed point extracts the continuous part of the component, while curved surface fitting and B-spline curved line fitting at the edge of the continuous part recognize the neighbor domains of the same component divided by obstacles' shadows. The ICP (Iterative Closest Point) algorithm conducts a registration of the two sets of data after the proper registration's direction is decided by principal component analysis. By experiments conducted at the shipyard, 200 curved shell plates are extracted from the scanned point cloud data, and registrations are conducted between them and the designed CAD data using the proposed methods for an accuracy evaluation. Results show that the methods proposed in this paper support the accuracy evaluation targeted point cloud data processing efficiently in practice.

Keywords: Point cloud; Region growing method; B-spline curve; ICP; K-d tree

1. Introduction

While efficiently evaluating the accuracy of the ship component has been considered important for many years as a necessary part of planning and control of production in shipbuilding, using point cloud data scanned by noncontact 3D laser scanner has only recently been taken into consideration [1]. As an application of laser scanners to shipbuilding, an accuracy evaluation system for ship components was developed at the University of Tokyo [2, 3]. The procedure is as follows:

(Step 1) Obtain the point cloud data by scanning the component using the noncontact 3D laser scanner.

(Step 2) Extract the part of the component from the point cloud data using basic region growing method.

(Step 3) Conduct a registration of the component's measured point cloud data and the design data using ICP algorithm directly.

(Step 4) Find the displacement errors by comparing the position of the two data and visualize them as the accuracy evaluation result.

Two vital problems exist here.

(a) In Step 2, the part of the component cannot be extracted efficiently due to irregular obstacles endogenous to manufacturing workshops and their shadows divide the component's measured point cloud data into several separated domains. Manual extraction and integration of these separated domains waste a lot of time and is a barrier for practical application. The well-known methods for calculating smooth surfaces from noisy point cloud such as moving least squares (MLS) projection [4] has the same problem that the whole component cannot be extracted at one time when the component is separated by the obstacles' shadows.

(b) In Step 3, an ICP (Iterative Closest Point) algorithm is used to conduct a registration between the measured point cloud data and the design data. Due to the features of the ICP algorithm, without a clear registration direction presetting, the registration of the two data

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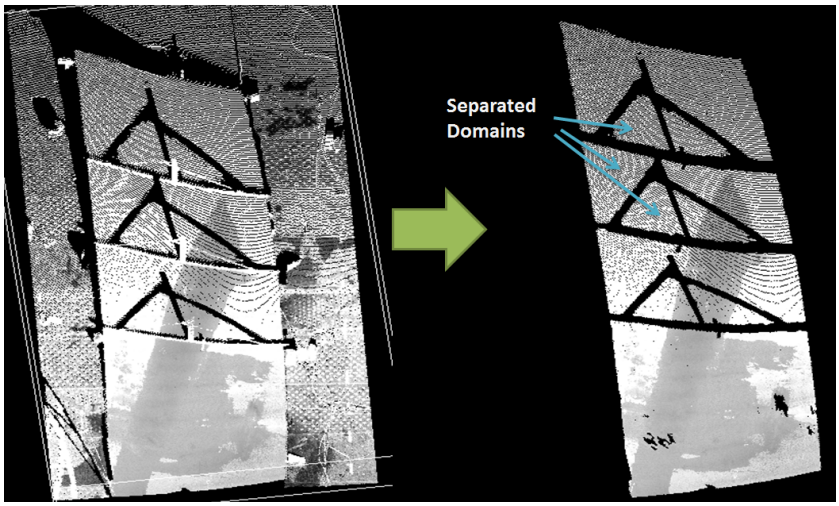

Figure 1. Component extraction.

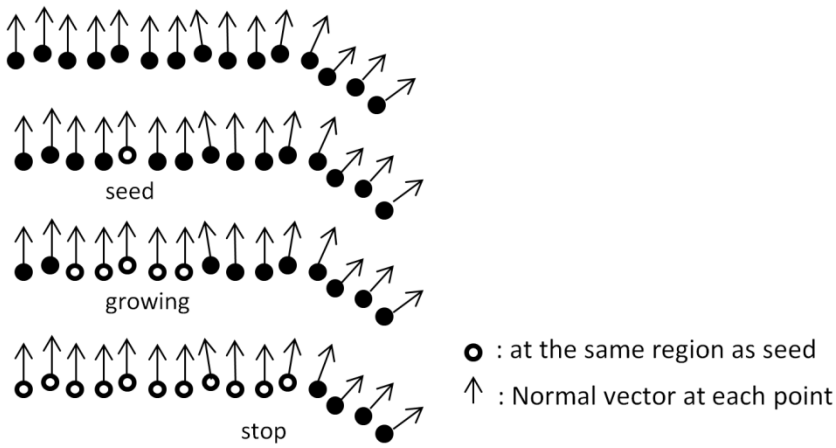

Figure 2. Region growing method.

sets could go in the wrong direction and lead to improper registration results.

As a result, existing point cloud processing methods (the basic region growing method and ICP registration method) can rarely satisfy the accuracy evaluation target in shipbuilding without significant improvements and appropriate combination.

This paper presents a reformative component extraction method solving problem (a) and a reformative component registration method solving problem (b) for the component's accuracy evaluation in shipbuilding. First, k-d tree construction is performed on the scanned point cloud data to fasten the neighbor searching of each point. To extract the continuous domain of the component from the point cloud data, a region growing method is performed on every neighbor point of the seed point. Then the neighbor domain, which is separated by obstacles' shadows from the extracted domain, is recognized by conducting curved surface fitting and B-spline curved line fitting at each edge point of the extracted domain. The whole component can be extracted by repeating the above steps. Before registering the extracted point cloud data of the component and the designed data, proper registration direction is decided by performing registration direction analysis on the two kinds of data. And then, ICP is applied for the following registration.

2. Component extraction

In shipbuilding, depending on the conditions in the factory, the laser scanner measured results of components (see Figure 1 left) cannot satisfy the accuracy evaluation requirement due to the following factors:

(1) The measured point cloud data always includes a lot of needless noise, such as the floor, the workers and some wooden templates which are necessary templates for the manufacturing.

(2) The measured point cloud data are usually divided into multiple separated domains by these obstacles' shadows. Manual extraction and integration of these separated domains wastes a lot of time.

A. The measured point cloud data always has a large amount of points which slow down the extraction process dramatically under the