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Development of an Inspection System for Defect Detection in Pressed Parts using Laser Scanned Data

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Abstract

In past few decades several researches have been conducted in the field of 3D parts inspection system. The accuracy level of manufactured parts has been improved remarkably within this period. The use of laser sensors in 3D part measurement process has introduced a significant improvement in data acquisition process regarding time and cost. However for quality control process, due to lack of appropriate technique to process and inspect the scanned point cloud data, high accuracy level could not have been achieved so far. Therefore the industries are still compelled to use same traditional coordinate measuring machines (CMMs) despite of being very slow. In this paper, a robust inspecting technique to detect defects in 3D pressed parts has been proposed. Point cloud data are segmented for the extraction of features. These segmented features are used for shape matching during feature based registration process to localize them with the respective CAD model and bring into same coordinate frame. A modified Iterative closest point (ICP) algorithm is proposed for the registration process. After the registration has been completed these scanned model and CAD model are compared to find defects in the manufactured parts.

Keywords: Inspection system, Pressed parts, Segmentation, Point cloud registration, Iterative closest point, Laser scanner

1. Introduction

Inspection process in manufacturing engineering has always been considered to be a crucial part. Due to high demand of flawless products, the necessity of better automated quality inspection system has raised to an enormous amount. Currently, coordinate measuring machines (CMMs) are widely used in the fields of quality inspection

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system for measurement of data from manufactured parts. They use touching probes to acquire the 3D point data. These contact based CMM machines have extremely low scanning speed and highly prone to scratch, therefore not suitable for parts made up of soft materials[1]. That is why these CMM machines are gradually being replaced by high speed laser scanning system to overcome these problems.

In past several years, many researches have been conducted in the field of laser scanner and laser scanned data processing system. A system for gross geometric feature inspection using dense range data was discussed in Marshall and Martin (1991)[2]. Newman and Jain (1995) presented an automated visual inspection system for detecting defects of castings by using range images. The system was only applicable to the class of objects containing planar and/or quadric surfaces. Localization was based on the assumption that the expected orientation of the parts was known. Therefore, the system only needed to solve three translational equations and one rotational equation[3]. Thompson et al. examined the reverse engineering of designs by generating surface and machining feature information off of range data collected from machined parts[4]. Langenbach et al. (2001) discussed an automatic visual inspection system for small stampings. This system could detect defects such as cutoffs, incomplete stampings, cracks, and scratches. The localization was a 2-D process[5]. The method of Osada et al. creates an abstraction of the 3D model as a probability distribution of samples from a shape function acting on the model[6]. The method introduced in Prieto et al. (2002) conducted visual inspections of common mechanical parts and made comparisons between measurement surfaces and their CAD models[7]. Novotni and Klein demonstrated the use of 3D Zernike descriptors[8]. Kazhdan et al. compared 3D models with spherical harmonics[9]. Besl P. J. and McKay N. D. (1992) proved that the ICP method will monotonically converge to the local minimum[10]. Yoon, H. S. et al. (2013) used stereo vision technique to capture the deformation on the roof caused by vehicle rollover and compared these images with the standard shape to measure the damage due to rollover[11]. In this paper, we propose an automated technique to process the raw point cloud data obtained from the laser scanning system and compare these point cloud data with the existing CAD data. For this purpose we have used the registration process to align both data in same coordinate frame precisely using modified iterative closest point (ICP) algorithm. Here we focused on matching of point clouds to CAD mesh models. We used polygonal mesh models as the approximation of CAD models in our work. From the polygonal mesh, different transformation invariant attributes can be extracted as the means of similarity among 3D models.

Nomenclature

M, S	model data, scanned data
N	number of points
Rot	rotation
$Trans$	translation
d	error distance
m	model data point
s	scanned data point
Φ	alignment function
λ	weighting factor
n	normal

2. Systematic procedure of the inspection system

The final goal of this research is to obtain a complete 3D point cloud data from several patches of point cloud data obtained from the laser scanner and compare these data with existing CAD model. The whole process consists of several steps to be carried out before comparison of point cloud data with CAD model. Since the data is only the 3D points representing the surface of the object, it is necessary to differentiate all the faces from each other for which segmentation is carried out. Then out of these segmented surfaces, some surfaces which influence the whole

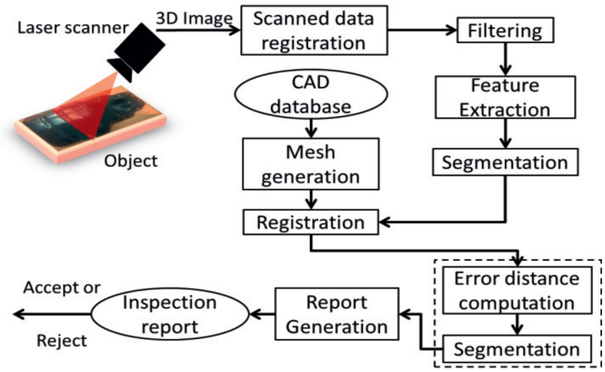

Fig. 1. Schematic procedure to represent the inspection system. [1]

geometry are chosen and used for the surface matching between point cloud and CAD data. For the matching process the scanned model and the CAD model located in their respective coordinate systems are needed to be transformed into a single coordinate system by the process of registration. The overall process of inspection system development is shown in figure 1.

3. Inspection process for the defect detection

3.1. 3D Data acquisition and segmentation process

A commercial 3D laser scanner system was used for the acquisition of 3D point cloud data. Scans were done from different view and several patches of 3D point cloud data were obtained which were then stitched together to obtain complete 3D view of the oil pan. During the process of scanning some of the outliers are also captured which are needed to be filtered before further processing is carried out for inspection. These outliers were manually selected and trimmed from the point cloud data of oil pan.

After scanning and preprocessing is completed, segmentation process is carried out to categorize different features of the parts based on the orientation of their normal. We proposed to use region growing segmentation algorithm for this purpose. It is carried out by detecting edges between different surfaces using normal orientation of the points on those surfaces and then surface planes are extracted. The algorithm then picks a random point from one

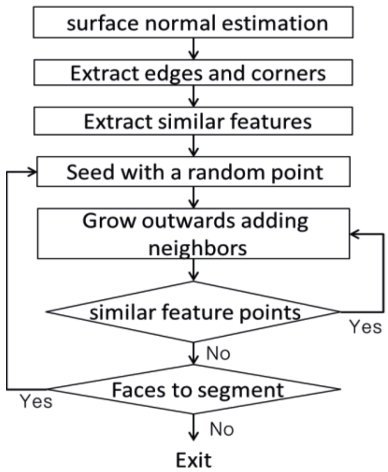

Fig. 2. Schematic representation of region growing segmentation algorithm.

of the surface and segments it then starts growing outward adding all the neighborhood points. It keeps on growing until it finds similar feature points. After completion of segmentation process in one face same process is carried out in other faces. These steps are repeated until the termination criterion is reached. Region growing algorithm for segmentation is explained step by step in figure 2.

3.2. Registration

Scanned point cloud data and the designed CAD model are not situated in the same coordinate system. Therefore, it is necessary to establish a relationship between these two different coordinate systems before making a comparison between scanned and CAD models. In this research a modified ICP algorithm is applied for the purpose of registration.

Let *M* and *S* be a model and scanned point sets as shown in figure 3(a) and let us assume number of points in *M* and *S* are equal,

$$N_M = N_S \tag{1}$$

Each point s_i corresponds to m_i

The Mean Squared Error (MSE) objective function is given by,

$$f(R,T) = \frac{1}{N_S}\sum_{i=1}^{N_S}\left(\left\|m_i + Rot(s_i) - Trans\right\|^2 + \lambda\left\|n_{mi} + Rot(n_{si}) - Trans\right\|^2\right) \tag{2}$$

In equation (2) $\left(\left\|m_i + Rot(s_i) - Trans\right\|^2\right)$ and $\left(\left\|n_{mi} + Rot(n_{si}) - Trans\right\|^2\right)$ are Euclidean distance from points s_i to m_i and distance of normal at point s_i to the normal at point m_i respectively and λ is the positive value weighting the influence of the normal-to-normal distance term .

The alignment function is obtained as given below:

$$\left(rot, trans, d_{mse}\right) = \Phi\left(M, S\right) \tag{3}$$

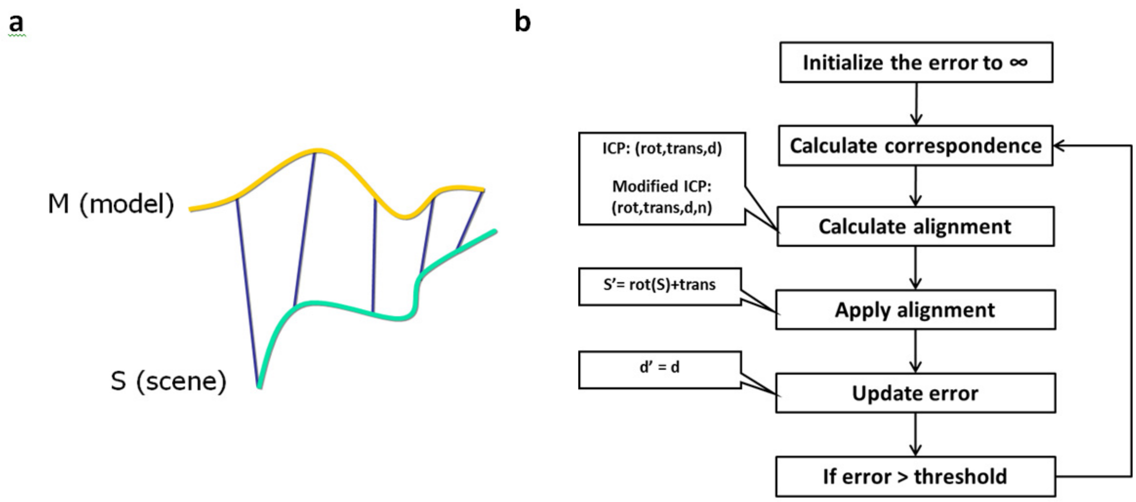

Fig. 3. (a) Illustration of registration process using ICP algorithm (b) Schematic representation of registration algorithm.

4. Experiments and results

Experiments were carried out to test the modified ICP algorithm and then compared with the registration result obtained from the point to point ICP algorithm proposed by Besl and Mckay[10]. The results are compared in figure 4. It was possible to automatically register both the surfaces very precisely with modified ICP algorithm. In figure 4, (a) shows the initial position of the two patches of scanned data, (b) shows the registered patches using the proposed modified ICP algorithm, (c) shows the error on the patches during the registration process, (d) shows the registration of patches using point to point ICP method and (e) shows the error result of the point to point ICP method. As we can see in the figure below that the surface interpenetration measure in the proposed method (figure 4(b)) is more even in comparison to the Besl and Mckay method in figure 4(d). Moreover from error distribution value in figure 4(c) and 4(e) we can see that the maximum error in (c) is 0.041990 mm whereas in (e) the maximum error value is 0.503182 mm. Besl and Mckay method gives higher accuracy when the surfaces to be registered are close enough, whereas our method involves normal orientation of points on each surface better registration result can be applied with this method in comparison to point to point method.

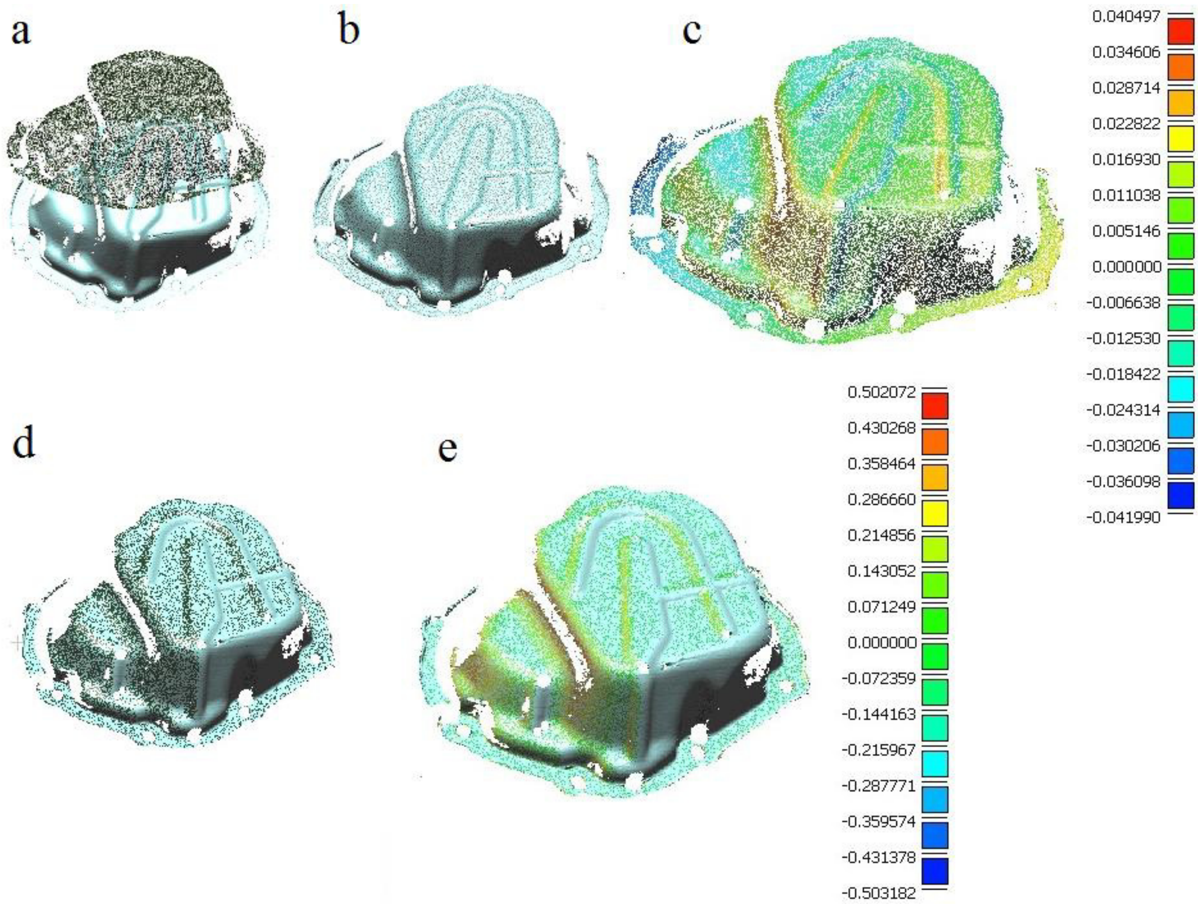

Fig. 4. (a) initial position of two patches (b) position after registration (c) visualization of error distance between registered patches (d) Registration with point to point ICP algorithm(Besl and Mckay method).

5. Conclusion

In this paper, we proposed an automated inspection system for automobile parts that uses laser scanned point cloud data. The system is not only limited to automobile parts but also can be applied in wide range of application. The system developed using proposed technique is able to segment the point cloud data of pressed parts and extract different features of the complex shaped surfaces. Using the extracted features, the point cloud data with its CAD model can be matched to align them together in the same coordinate system to make the comparison process more precise. Then the system computes the point to plane distance to calculate the error level in scanned object and displays the result and makes a correct decision to identify the defected samples.

As a future work, this research will be dedicated in developing the technique further more to enhance the accuracy and speed. Attempts have been being made to empower the system by widening the application area of the system. In addition to the free form surface defects inspecting module, flatness measuring module is being developed to carry out variety of task by single system

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