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The use of low density high accuracy (LDHA) data for correction of high density low accuracy (HDLA) point cloud

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ABSTRACT

Coordinate measuring techniques rely on computer processing of coordinate values of points gathered from physical surfaces using contact or non-contact methods. Contact measurements are characterized by low density and high accuracy. On the other hand optical methods gather high density data of the whole object in a short time but with accuracy at least one order of magnitude lower than for contact measurements. Thus the drawback of contact methods is low density of data, while for non-contact methods it is low accuracy. In this paper a method for fusion of data from two measurements of fundamentally different nature: high density low accuracy (HDLA) and low density high accuracy (LDHA) is presented to overcome the limitations of both measuring methods. In the proposed method the concept of virtual markers is used to find a representation of pairs of corresponding characteristic points in both sets of data. In each pair the coordinates of the point from contact measurements is treated as a reference for the corresponding point from non-contact measurement. Transformation enabling displacement of characteristic points from optical measurement to their match from contact measurements is determined and applied to the whole point cloud. The efficiency of the proposed algorithm was evaluated by comparison with data from a coordinate measuring machine (CMM). Three surfaces were used for this evaluation: plane, turbine blade and engine cover. For the planar surface the achieved improvement was of around 200 μm. Similar results were obtained for the turbine blade but for the engine cover the improvement was smaller. For both freeform surfaces the improvement was higher for raw data than for data after creation of mesh of triangles.

1. Introduction

Coordinate measuring techniques rely on computer processing of coordinate information from a measurement. Dimensions, forms and locations of geometric features on parts are determined on the basis of coordinate values of gathered points on the part surfaces. These points can be gathered using contact or non-contact methods [1,2].

From contact measurements points generally having high accuracy are obtained. The measuring process is not generally robust. The disadvantages are slow measuring speed, limitations in the size of the part and the necessity to fasten the part [3,4].

Today, faster and more thorough inspection of machined parts is demanded. Therefore optical methods are increasingly popular. In these methods data of the whole object is gathered in a short time. Unfortunately, the accuracy of data is lower than in case of contact measurements [5,6] as there are many factors affecting accuracy. Although manufacturers try to increase accuracy of non-contact devices their total accuracy depends on production application and currently it is down to 50 μm [7].

Optical methods may include: triangulation, ranging, interferometry, structured lighting and image analysis. Within this article laser scanners based on triangulation were used. They are more accurate and cheaper [1] than other non-contact measuring techniques. To obtain knowledge about measuring error a quick verification test can be performed [8]. A reference plane is measured from different positions and orientations of the laser scanner. Then a least square plane was fitted to the points, and the

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maximum residual provides the value of the maximum expected measurement error.

Much effort was devoted to overcome limitations coming from laser scanning, mainly by error compensation. Xi et al. [9] presented the method of laser scanner's error compensation. For this purpose artefacts composed of balls and planes were used. They observed that measurement error depends on angle and scan depth. For a sphere, as for other elements of simple geometry, incident angle is easy to calculate. An empirical formula for error estimation was determined based on experimental research for various scan angles and depths.

Other methods to overcome limitations of a single sensor are multisensory architectures and data fusion [10–14].

Boudjemaa et al. [15] named four methods of data fusion: fusion across sensors, fusion across attributes, fusion across domains and fusion across time (filtering). In fusion across sensors the same property is measured by different sensors. In fusion across attributes different quantities, but connected with the same experimental situation, are measured by different sensors. In fusion across domains the same attribute over various ranges or domains are measured by different sensors. Finally, fusion across time, merge new data with historical information.

Several methods for data fusion were developed. A common approach is to use information from non-contact device to create coarse CAD model of the measured object. Then this model is used to perform inspection using a contact probe [11,16–18,4]. It is particularly important when the CAD model of the measured object is not available [2].

Fusion across attributes consists of measuring the part with different devices and then replace data which cannot be measured by one method by data from a more suitable one. For example, when the measurand has small cylindrical holes which cannot be measured by optical systems, information about these features are obtained from contact measurement [2,11,13,19,20]. Unfortunately this method can only be used to improve measurement of the part with accuracy features and is not suitable for freeform surfaces.

An interesting approach was presented in [21]. The authors proposed a method of data fusion from multi-resolution sensors. After measurement of a part using two types of devices features in both are detected. Then Points of Interest (POI) or Regions of Interest (ROI) are used to create merged model. Points/regions from both methods that are closer to initial model are taken to create merged model. Authors did not present how their algorithm would work for free-form surface without features.

The subject of data fusion was also considered by Hannachi et al. [22]. In their approach more accurate system reconstructs the outline of the object, while the less accurate one is used to characterize its 3D surfaces. In this approach distortions in measurements of the surfaces are not corrected.

Recently, a novel method for data fusion was presented by Senin et al. [10]. In their approach an iterative closest point (ICP) algorithm is used. This algorithm aligns iteratively a point cloud from optical measurement to data from point measurements by finding corresponding points. As the ICP algorithm requires to have points arranged in a regular grid, for optical measurement methods only structured light scanner can be used.

It was shown that existing methods of data fusion have some limitations. Many of them are inadequate for freeform surfaces. Optical devices are often used only to lead tactile probe. The ICP algorithm provides only rigid-body transformations which does not improve the shape of a point cloud.

Hence a novel data fusion across sensors method, not susceptible to the form of input data was developed for which a regular grid of input data is not required. The two sets of fused data have fundamentally different nature: high density low accuracy (HDLA) and low density high accuracy (LDHA). The proposed data fusion method was verified on the basis of data from contact method and laser triangulation.

2. Description of the concept

Research on the properties of optical measuring methods, particularly laser triangulation, showed that this type of measurements provide data with both systematic and random errors. To present how systematic errors influence the accuracy of a measurement a simple test was performed. A planar surface was measured using laser scanner. Then from the whole point cloud a single cross-section was selected and compared with the same cross-section measured using a contact method – CMM. The results are presented in Fig. 1.

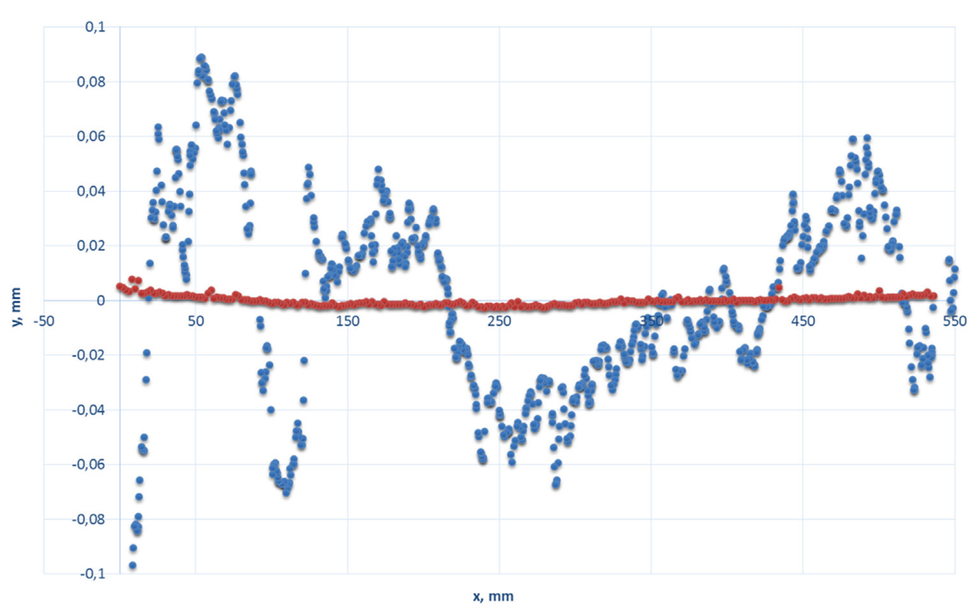

Fig. 1. A single line measured with two different methods.