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A surface extraction analysis in a multi-material test part for computed tomography in metrology applications

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Abstract

The main advantage of Computed Tomography is the capability of making measurements of non-accessible internal features in a test piece. One of the cases that can usually be found in this sense is the contact zone between two elements that are forming a common surface boundary, where the main complexity is to determine which surface belongs to which piece. Nowadays, this kind of surfaces are measurable only by utilizing Computed Tomography, taking into account that the characteristics of the Tomography can significantly vary depending on the material of the elements that are in contact. In this article a piece that has two different interfaces is analyzed: a Piece in contact with Air, and Material A in contact with Material B. Three different surface extraction algorithms are analyzed for multi-material parts, Threshold, Canny and Deriche, and the results and conclusions obtained are presented.

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1. Introduction

Computed Tomography (CT) for metrology applications is now a reality, since it is more and more applied in the current industry. Its main feature is the possibility of making measurements in non-accessible areas. When these

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measurements are carried out, one of the main difficulties is the access to the transition between two different materials, so that any measurement in this type of areas is only possible by destructive tests unless tomographic techniques are used [1].

The basic function of CT scan is to generate a 3D model of a piece, obtained by means of the interaction of the X ray beam source, the work piece and the X ray detector. It is well known that one of the most critical issues is the surface extraction process, since it has an important influence in the accuracy in measurements. The most common surface extraction method for commercial CT System is based on gray value thresholding. This gray value is highly dependent on the material, the material interface and the radiation. Different to how it is in CT Medical applications, where the grey values are standardized in Hounsfield units, in industrial applications of CT this turns out to be impossible due to the great quantity of existing materials. When working in a mono-material piece, grey value definition is only needed for the piece and the air; however, in a multi-material piece this definition is much more complicated due to the numerous grey values needed, this being one for each material present in the piece.

There are some studies for computer image and vision applications that evaluate this kind of methods but normally they utilized artificial images or images obtained in controlled conditions, which makes it very difficult to replicate with real tomography. In the other hand, there are some real metrological applications where the surface extraction is analyzed on multi-material parts. For instance, in [2-5] measurements between elements in direct contact to each other are made as well as measurements of gaps between different materials; and in [6] the changing material thickness is analyzed in order to know how this influences the remaining intensity after the radiation passes through the workpiece, being made by means of the fusion of multi-energy stacks. All the investigations mentioned before apply a surface extraction method based on grey value thresholding. For that reason, in this article two methods based on discontinuity detection are analyzed for the surface extraction process.

The test part used in this article has three main features: 1) It has a mono-material zone with an interface of Material A in contact with Air, 2) it has a surface forming a common boundary of two elements which made another interfaces when Material A is in contact with Material B and 3) it has measures which are not influenced by the surface extraction algorithm. The specific problem present in the interface between materials is that the tomographic characteristics of this interface changes with respect to that air-piece reference when the air is substituted by different materials, producing an unlimited variety of combinations [7]. This aspect raises the need to analyze the behavior of the different segmentation algorithms in order to obtain metrological capabilities. Therefore, a multi-material workpiece is been designed with interfaces between materials. This piece has characteristics that are useful to analyze the influence of the use of the different algorithms on the surface extraction among other things because the effect of the other influences can be compensated.

For the purposes of this investigation, a General Electric Computed Tomography (CT) system is utilized, and different surface extraction algorithms (Threshold, Canny and Deriche) are analyzed for multi-material parts. The piece of study is composed of two elements: male and female make of different materials. In each one of the sections the equipment utilized is presented, as well as the results and conclusions obtained.

2. Methodology

For the purposes of this research, there are some special considerations that must be taken into account in each of the stages in order to obtain a reliable and accurate measurement (example: Scaling factor correction and surface extraction procedures), explained in detail in [8,9]. Fig. 1 shows a summary of the procedure used.

Fig. 1. Methodology.

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