Dimensional Inspection of Manufactured Parts with Web-Based 3D Visualization

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Short Abstract: Non-destructive Dimensional inspection is becoming a key part of many manufacturing processes where the final assemblers require very tight tolerances. This paper describes an integrated solution that enables ubiquitous access to the metrology data in real time generated by an optical 3D scanner. The main contribution is the use of new standards for 3D visualisation on the web, which compared with existing solutions expedites the supervision of the health of the manufacturing process, facilitating decision making, and enabling further analysis of large metrology series by means of big data techniques.

Key words: Industry 4.0, Metrology, Cloud Computing, Visual Computing, Virtual Reality for Engineering.

1- Introduction

Nowadays companies are facing a very competitive business environment where rapid decision making has become critical for their success. This decision making process implies having tools to quickly analyse data from multiple sources in order to gather valuable information.

The upcoming industrial revolution has already reflected this necessity in many international initiatives, like the German *Industrie 4.0* [KW1] or the American *Industrial Internet*. From their perspective the connected factory is the key for the success, where the data generated in the shop floor becomes a very valuable asset for any manufacturing environment.

In the case of dimensional inspection process, existing tools, such as Geomagic [LL1] or CloudCompare [G1,] are not adapted to this workflow. The standard approach consists in generating closed reports that workers analyse subjectively without the possibility of implementing any advanced analytics. In contrast, the dimensional inspection tool described in this paper is focused to satisfy the demands of emerging tendencies around Industry 4.0 initiative, where the use of technologies related to ubiquitous and real-time data, including visual computing, are key aspects, according to Posada et al. [PT1]. It has been designed using a human-centric approach providing individual tools to the different players involved into the metrology process. Moreover, the data flow can be fully integrated into a connected smart factory allowing the implementation of advanced analytic tools using big data techniques. The processing workflow presented is comparable to that described in [ZW1] but adds more automation and data centralization. Previous works have compared non-contact inspection with contact systems based on CMMs and stressed the importance of scan to reference alignment ([M1], [MA1], [GW1]). The following sections describe our non-contact dimensional inspection solution, including alignment, measurement and visualization.

2- Implementation

Our non-destructive dimensional inspection solution processes 3D point clouds coming from a structured light scanner that can capture more than 3 million points for each analysed object. The implementation provides three different tools for defining the measurement process, performing the measurements, and to visualise the results using an interactive 3D viewer. Each one of these tools targets the roles of the metrologist, machine operator, and production manager respectively.

The input point cloud is processed in the shop floor using the measurement tool that executes the metrology plan that is defined using the measurement definition tool. The output is the distance of each point of the point cloud to the corresponding point in the CAD reference model. These distances are then visualised as a colour map. These data is sent to a database in the cloud and can be accessed through a 3D web viewer using any standard web browser. Colour maps have already been used in surface metrology results visualization (e.g. [MR1]), but not in a centralised web- based system as proposed in this work.

Following sections describe each of these tools in detail.

2.1 – Measurement definition tool

The definition tool has been designed to specify the alignment procedure and tolerance parameters of each reference model.

The alignment is performed by specifying a set of 3D primitives (planes, spheres, etc.) that approximate some relevant regions of the CAD reference model. These primitives are used to register or align the input point cloud with the CAD reference model in the same reference frame. In this way, the fitting is the optimal from functional requirements of the part. Figure 1 shows an example defined by a plane and a sphere.

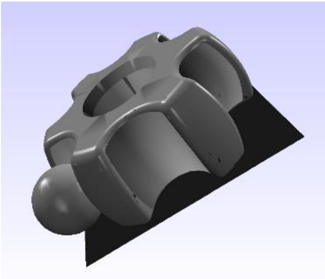

Figure 1: Reference definition.

2.2 – Measurement tool

This tool executes the inspection process comparing the points cloud coming from the 3D scanner with the CAD reference model that serves as the theoretical reference. It has been designed to work in the shop floor autonomously without the need of human intervention. In this way, the tool is constantly monitoring the scanner, starting the inspection process automatically as soon as new data become available.

The comparison algorithm tries to fit the primitives that define the reference with the input from the scanner. During this process the point cloud is sequentially processed as follows:

1. **Outlier removal:** points not corresponding with the part being analysed, such as the scanner fixture, are automatically removed from the input cloud.
2. **Alignment:** the coordinate systems of the reference model and the captured points are aligned using a best fit strategy so that they both lay in the same absolute reference frame. It is important to note that this alignment may not be the optimal one from an engineering perspective but it eases the primitive fitting.
3. **Primitive fitting:** having the input point cloud aligned with the reference model, it is possible to determine the points that most probably belong to the reference primitives by means of their distance. These points are then used to estimate the real parameters of the theoretical primitives finding their equivalents into the input point cloud. These equivalents are used to perform the final alignment by fitting the input data with the reference primitives.
4. **Comparison:** finally, the distance of each point to the CAD reference model is computed and displayed as a colour map, distinguishing the zones lacking material with those with excess. Figure 2 shows the final result. At the same time the result is sent to a database in the cloud so that it can be remotely visualised and analysed.

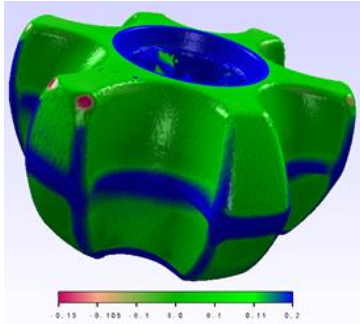

Figure 2: Result of the dimensional analysis.

The whole process needs about 60 seconds to process 3 million points in an Intel Core i5 @ 3.2GHz processor. Compared with commercial solutions it runs about 5 times faster with similar accuracy levels.

2.3 – Web Visualizer

All data resulting from the measurement of a part is stored in a server for remote visualization. Engineers and metrologists wishing to monitor the quality of manufactured parts can access the centralised web site and inspect results interactively. If necessary, users can create a report document for an inspected part (as a PDF document).

The visualization web presents the user a list of the available scanned parts. New scanning results are immediately shown to the remote user. The list can be filtered based on scan date and/or reference CAD model. Upon selection of a scan, the corresponding part is loaded and displayed in 3D using a colour map as shown in Figure 2. Additionally, some metadata is displayed, including a histogram of the dimensional error values of the whole part.

The 3D viewer has the following functionality:

a) **Interactive view manipulation**: The user can manipulate rotation and panning of the part using the mouse, buttons and wheel.

b) **Point error inspection**: By clicking at specific points on the 3D surface the user can inspect dimensional errors. A measurement of the distance in millimetres between real and theoretical part at the clicked point is displayed.

c) **Labels**: The user can add labels on the virtual part to highlight relevant errors at the inspection points. These will be shown to other users who access the same scanned part.

d) **Snapshot images**: The user can store pictures of the part in different points of view. They will also be shown to other users and will be included in the printed report.

Two types of rendering have been implemented. One in which the scanned part itself is drawn with the error colour map, and one in which the theoretical CAD shape is drawn with the same colour map.

The current implementation uses HTML5 and WebGL for interactive 3D rendering. The back end uses MongoDB as a database for scanned part data storage together with an Apache web server and PHP scripts. The measurement tool communicate with this cloud application through a web service. For every new CAD reference and scanned part it informs the application and sends its measurement results so that they become accessible.

Figure 3 shows a screenshot of this tool.

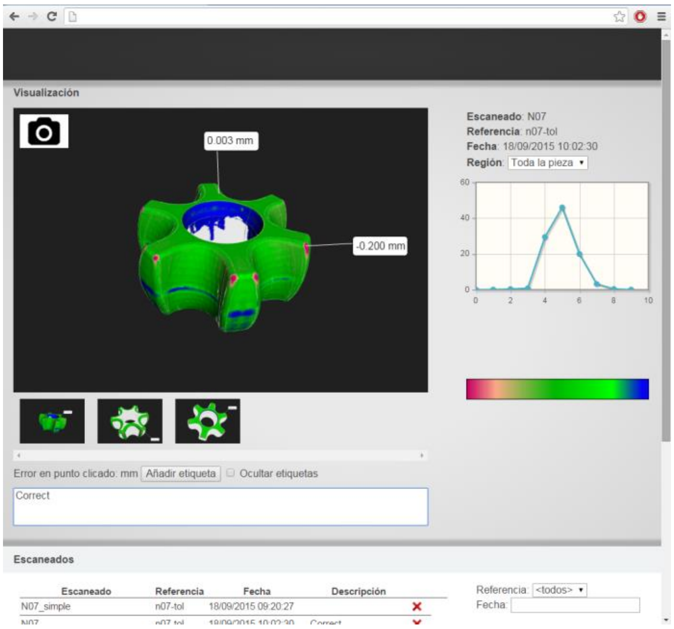

Figure 3: Web visualizer.

4- Conclusions and Future Work

In this work we have implemented a new workflow for dimensional inspection processes that solves two of the main challenges that new industrial standards are pushing: human centric tools and connected smart factories.

Our approach provides personalized tools for each role that takes part into the metrology workflow tailored to their specific needs. In addition, it provides cloud connectivity with an innovative interactive report viewer that allows to control the process in real time by using any device equipped with a Web browser.

In conclusion, it can be said that the most important contribution of this work is the real time ubiquitous access to the metrology information that allows an early detection of problems in the manufacturing process. This fact accelerates the decision making by reducing the amount of rejected parts, and thus directly impacting into the manufacturing costs.

As for the future, the cloud implementation allows to integrate advanced analytics tools through big data techniques. The resulting dimensional data is a very powerful information source that has the potential to reflect the state of many parameters of the whole production line. In this way it would be possible to correlate these parameters automatically, predicting manufacturing problems before they happen, such as tool wear for example.

In addition, the cloud infrastructure also enables to implement advanced traceability procedures that are increasingly being demanded by customers.

5- References

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