Good practice guide for mapping task-specific measurement errors

Sean Woodward, Stephen Brown, Michael McCarthy

National Physical Laboratory (NPL)

Teddington, United Kingdom

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1 Scope

This good practice guide details worked examples relating to the measurement and analysis of data from the NPL Prismatic Dimensional Material Standard [1].

2 Introduction

This document is designed to be used as an example of procedures that may be followed when performing measurements using dimensional transfer standards and is in no way considered to be exhaustive, users are encouraged to develop their own tests.

The document assumes a competent operator will be using their chosen scanning system and undertaking the analysis in their chosen post processing software. The document is not intended as a training document for the use of 3D non–contact scanning systems or software analysis packages.

2.1 Scanning systems

The NPL Prismatic Dimensional Material Standard can be measured with a wide range of measurement systems. This best practice guide concentrates on using a non-contact stereoscopic fringe projecting 3D scanner, specifically a Breuckmann system.

It should be noted that the NPL Prismatic Dimensional Material Standard is not a calibration tool for non-contact stereoscopic fringe projecting 3D scanners. **The scanning system should be in good calibration prior to testing**.

2.2 Post processing software

After capturing high-density point cloud data, post processing software is often used to perform a broad range of tasks, including:- registration, alignment, filtering and analysis. This can often be performed within the software supplied with a 3D scanner but it is also possible to perform this in an external software package. Any errors in the software package used will propagate through to the final result. **It is important that the user is aware of the performance of the software package used, either through independent verification of the software package or through testing of the software where this is not the case**.

3 Terms, definitions, abbreviations and symbols

Some key terms to assist in the understanding of scanning and metrology tasks which are central to this document are listed and defined here.

3D SCANNER

The measuring system that is to be used, typically based on laser scanning or structured light.

ALIGNMENT

The process by which the measurement data is brought into the same coordinate system as the CAD model.

CAD COMPARISON

Comparison of a measured surface against a CAD model (whole or part). Often the comparison will be displayed as an error map which uses colour coding to represent the magnitudes of the differences. Alternatively, error vectors can also be produced and magnified to aid visualisation.

CAD MODEL

The 3D Computer Aided Design (CAD) model of the part being measured. This model is made available in STEP format and is used as a reference for the comparison of measurement data.

CALIBRATION

A controlled test usually involving a calibrated reference artefact. The internal parameters of the scanning system will usually be optimised as a consequence of the calibration result.

POINT CLOUD

A set of measured 3D data points.

REGISTRATION

The process by which measurement points captured from different measurement positions are amalgamated into a single coordinate system.

REFERENCE SURFACE

A surface against which the measured 3D dataset can be compared. The surface can be a CAD model, part of a CAD model or a geometric feature such as a plane.

SAMPLING

3D scanning systems typically produce very large data sets known as point clouds. Sometimes it is necessary to reduce the size of the data set through sampling, to speed up any subsequent data processing. Sampling reduces the data size by removing data points within the data cloud. There are several ways this can be achieved, an example of which is Poisson Disk sampling, which can reduce the number of points in a point cloud without losing detail. By reducing the number of points representing surface regions with low rates of change, while retaining larger numbers of data points in regions with greater rates of change, the surface can be accurately depicted with less data points.

TARGET MARKERS

Typically these are circular targets, although they can be any predefined shape, used by some scanning systems to identify the relative positioning of the scanner to the workpiece being measured. These points can then be used for the registration when multiple measurements are taken.

4 Preparation

4.1 Care of the material standard

Some objects to be measured will not have a sympathetic surface for measuring with an optical system and will require coating. Typically, fine coatings of powder, often white, are used to leave the surface with a specular surface. The NPL Prismatic Material Standard has been treated to ensure the Invar does not corrode but also to ensure it has a surface finish that is suitable for measuring using an optical scanner. This means that the artefact is ready to be measured without the need to apply a coating beforehand. This treated surface leaves the standard with a slightly textured finish which can pick up dust or other contaminants, it is therefore important to ensure that the standard is clean before use. It can be cleaned using ethanol or isopropanol and a lint free cloth or an air gun.

To minimise the possibility of contaminating the measuring surface with fingerprints it is important to ensure the user keeps their hands clear of the surface features that are to be measured. While the finger marks are unlikely to have a significant effect on the surface profile of the standard, their presence may change the optical properties of the surface and have an effect on the measurement quality. There are recesses cut in the sides of the standard to aid with the lifting of the standard and the bottom has been partially hollowed out to reduce the mass down to approximately 20 kg. Care should therefore be taken to ensure the standard doesn’t trap the fingers of the user.

3D optical scanners typically require the use of target markers when in use. Although markers can be stuck directly onto the surface of the object to be measured it is preferred that in this case they are attached around the object being measured on a framework that is held in the same frame of reference as the object to be measured. It is preferred that the target markers are not stuck directly onto the standard as removing the adhesive completely can be difficult on the textured surface of the standard.

It is recommended that the standard is placed on a rotary stage with reference markers attached to the stage, enabling it to be easily manipulated within the field of view of the scanner and measurements of the whole standard taken.

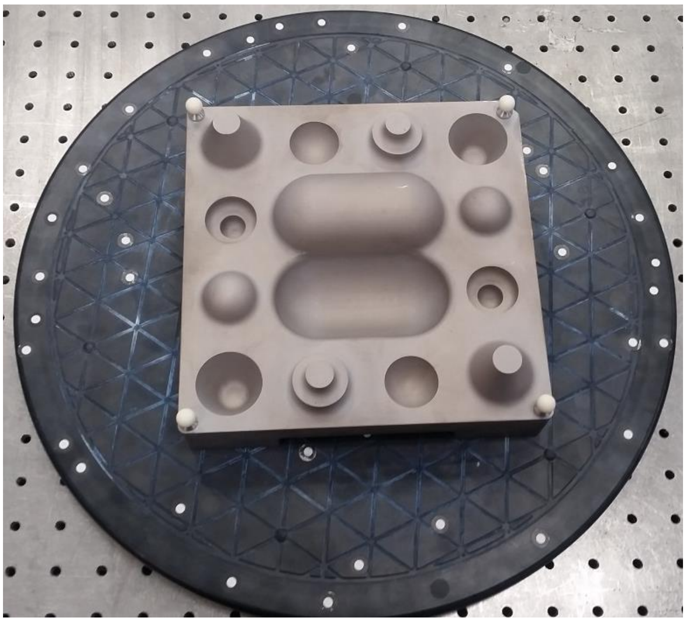

Figure 1. Image showing the NPL Prismatic Material Standard placed on a rotary stage with reference markers attached

4.2 Characterising of the 3D optical scanner

3D scanners often include a characterising procedure as part of their use. This characterising procedure usually involves the use of a characterising artefact; often a grid plate of black and white dots or a spherical object of known size. By measuring the characterising artefact in several orientations within the scanner volume it is possible to apply scale factor to the captured images and perform dimensional measurements with the system. Before any dimensional measurement is carried out, it is important to carry out the characterising procedure for the 3D scanner in accordance with the manufacturer’s instructions. As a reminder to the reader, leaving the scanner, characterising artefact and object to be measured in the environment to soak and reach an equilibrium temperature with its surroundings is recommended.

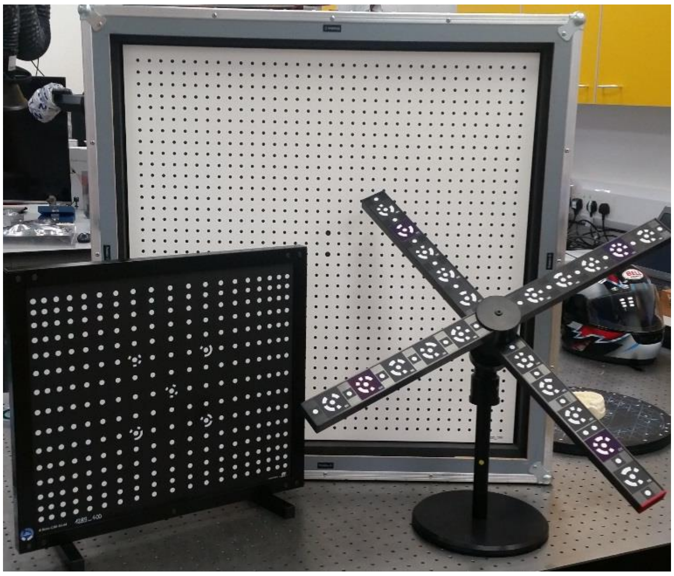

Figure 2. 3D scanner characterising artefacts

NOTE: The term calibration is often used in relation to the verification of 3D scanners. It is important to be aware that this is not strictly a calibration, as it does not provide dimensional traceability back to the SI. Technically it is a characterization, allowing the conversion of measurements taken with a 3D scanner to have dimensional meaning.

4.3 Analysing captured data

The data captured using the 3D scanner needs to be analysed. As mentioned previously the captured data can be analysed in either the software supplied with the system or another separate piece of software. Irrespective of which software package is chosen, the approach can be the same.

Before performing any scans, first open the CAD model of the NPL Prismatic Transfer Standard and import it into the software where the analysis will be performed. Then define the features of interest within the software package. This may be planes and other geometric features found on the surface of the standard or may be distances and dimensions between specific features. Defining these features first, before the scan data is captured or imported, allows the user to check they are correct before the software has too much data to process.

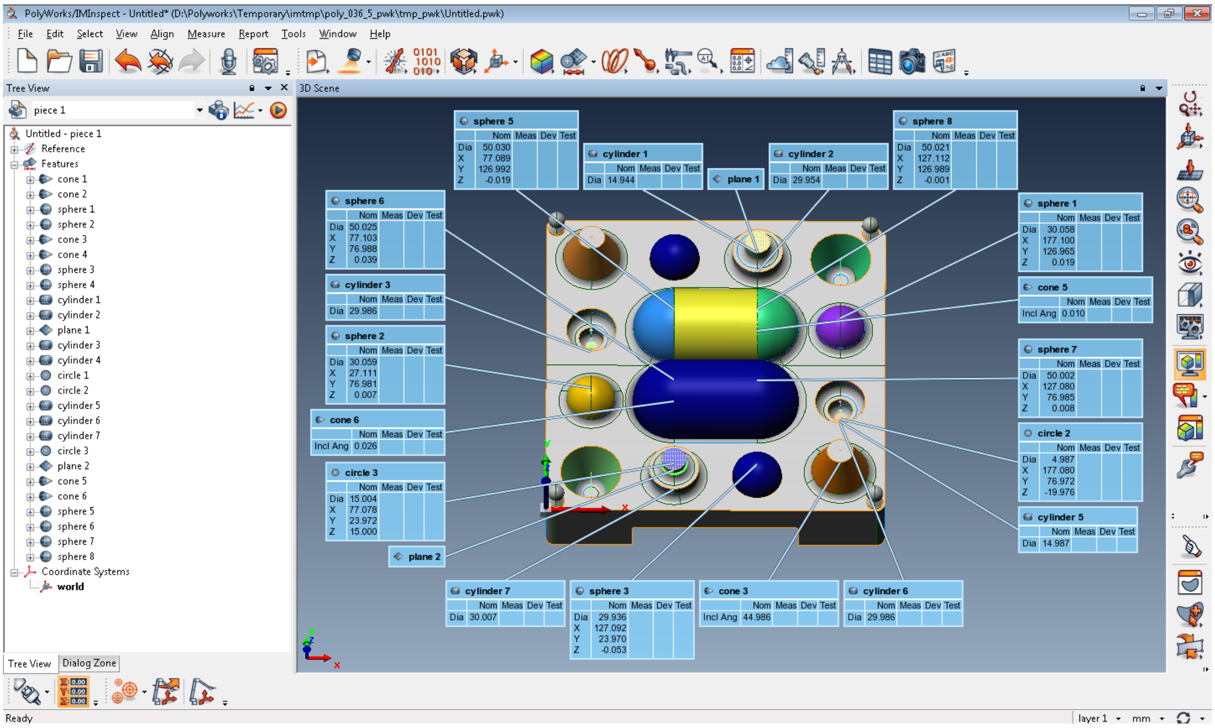

Figure 3. NPL Prismatic Transfer Standard with surface features defined, captured in Polyworks

5 Measuring surface features

This section describes measuring the surface features of the NPL Prismatic Transfer Standard. This type of assessment is used when the inspection of physical surface features is required, i.e. sizes of cylinders, flatness of planes, angles between edges etc.

The number of features measured may vary depending on the desired output, as it is acceptable to measure only the features similar to those being manufactured. Ensure the standard is clean and in an acceptable location, the scanner is calibrated and allowed to warm up, as per the manufacturer's instructions, and that the software to perform the analysis is correctly set up, as described in section 4. Ensure the settings of the scanner are correctly adjusted to allow the best possible data, considering the ambient lighting conditions.

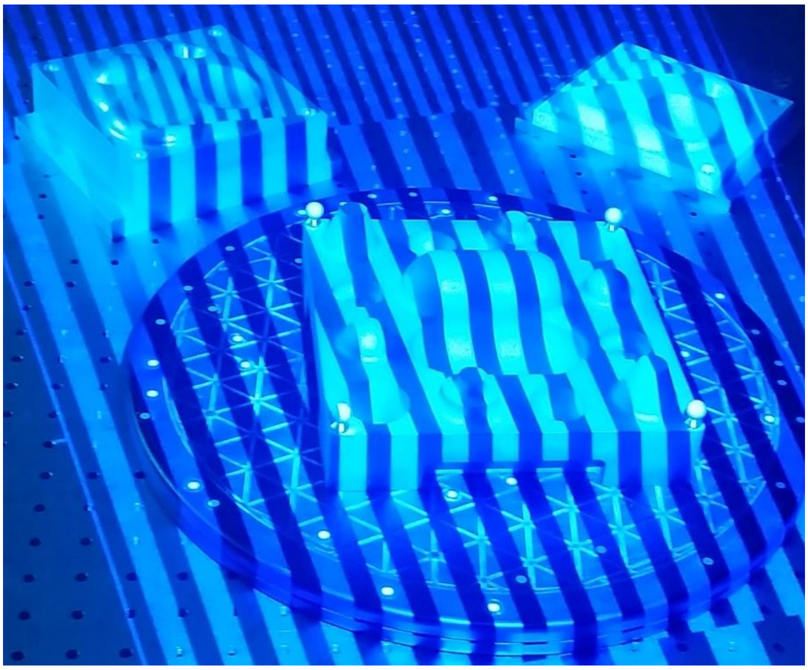

Figure 4. NPL Prismatic Transfer Standard being scanned by a blue light scanner

When scanning the prismatic standard, ensure the scanner is used in accordance with the manufacturer's instructions. Multiple exposures, at various angles are likely to be required to capture sufficient data to be able to represent the surface of the standard. Cylindrical and spherical surfaces will likely require more images captured on them compared to similar sized features with flat sides, due to the curvature of their surfaces. The internal features, such as the internal hemispheres, may produce multiple internal reflections and the settings of the 3D scanner will need to be adjusted to minimise the amount of spurious data captured.

Once the data has been captured it should be aligned to the CAD model. This can be done in a variety of ways but often a best fit alignment produces the best results. Where required, paired points on the scanned data and the CAD model can be selected to assist the software with the alignment. With the CAD model and the scan data aligned, it is possible to extract the required measurement data and report it in the method that best suits the user.

6 Measuring feature positions

This section describes measuring the relative positions of the surface features of the NPL Prismatic Transfer Standard. The type of assessment is used for two aims, measuring the ability of a machine tool to move accurately to a position within its volume or to assess the performance of a 3D scanner to measure within its volume.

Perform the measurements of the material standard, largely in the same manner as described in section 5, but only taking one image of the standard from one position. Align the data to the CAD model and again, extract the data of interest and report it in the method that best suits the user. Now take an additional single measurement, again from a single position. Repeating the measurement after rotating the alignment of the object may sometimes be useful, giving an assessment of the performance of the 3D scanner across its whole volume. Normally the relative positions of the scanner and the object to be measured change during the course of the measurement with the user moving the scanner around the object to get as much data as possible. By comparing information taken with a single exposure the user can gain information of how the scanner performs throughout its measurement volume.

7 References

[1] NPL, "TIM - 2.4.2 - A guideline containing directives which describe the procedures to be used for the calibration of the measurement standards TSMU-MS and TSEM-MS," 2014.