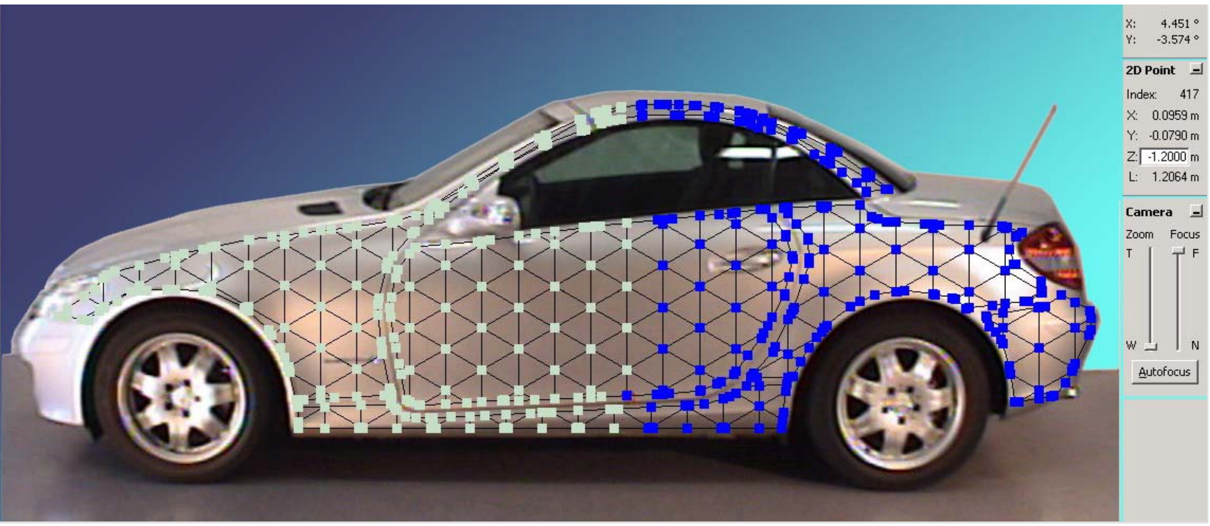
Application Note *VIB-G-03*



FIELD OF APPLICATION

- **A** Aerospace
- **B** Audio & Acoustics
- **C** Automotive Development
- **D** Data Storage
- **G** General Vibrometry
- **M** Microstructures & -systems
- **P** Production Testing
- **S** Scientific & Medical
- **T** Structural Testing
- **U** Ultrasonics

PSV Scanning Vibrometer: Scan Point Import

With the 1D and 3D Polytec scanning system you have 2 possibilities to define scan points: either you draw geometric figures on the live video image as you would do in graphics software or you import the object geometry (i.e. the 3D position of the measurement points on the object surface) from a universal file. The first method works well for flat objects but has limitations (1D) for objects with a non-flat surface or is not applicable at all (3D). The latter method, however works independent from the object geometry and is thus described in the following section.

3D-Alignment: Theory

The 3D-alignement is a prerequisite for the import of geometry data. It determines the spatial relationship between the object to be scanned and the laser scanning system.

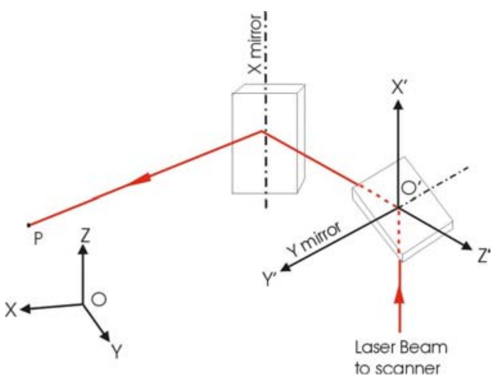


Fig. 1 : Global and local laser systems

An algorithm calculates the voltages to be applied to both x and y scanner controller so as to automatically direct the laser beam to the specific point.

To establish the geometric relation between object and scanner, we consider 2 different right-hand orthogonal coordinate systems as shown in Figure 1: the global system OXYZ in which the coordinates of the scan points are known and the local laser system O'X'Y'Z' whose axes are defined by those of the scanning mirrors and whose origin has the coordinates $(x_{o'}, y_{o'}, z_{o'})$ in the global system.

Let $l_{x'}$, $m_{x'}$, $n_{x'}$, $l_{y'}$, $m_{y'}$, $n_{y'}$, $l_{z'}$, $m_{z'}$, and $n_{z'}$ be the direction cosines of the X', Y', Z' axes in the global system.

If we consider a scan point P, the relation between its coordinates (x, y, z) in the global system and its coordinates (x', y', z') in the local laser system is given by [1]:

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François Bouteille
August 2004

$$
\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} x_{o'} \\ y_{o'} \\ z_{o'} \end{bmatrix} + \begin{bmatrix} l_{x'} & l_{y'} & l_{z'} \\ m_{x'} & m_{y'} & m_{z'} \\ n_{x'} & n_{y'} & n_{z'} \end{bmatrix} \cdot \begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} \quad (1)
$$

or

$$
[X] = [X_{o'}] + [T] \cdot [X'] \quad (2)
$$

where [T] is the transformation matrix from the local laser system to the global system. To determine [T] and $[X_{o'}]$, we use 4 reference points whose coordinates in the global system can be measured relatively precisely. When positioning the laser beam at the reference points, the scanning voltages applied to the scanners are recorded, which enables to relate the local coordinate to the scanning voltage.

Knowing the corresponding scanning angles and some geometric relations between both the scanners, the solution of a non-linear equation system yields the matrix $[X_{i'}]$, i =1,2,3,4 which are the coordinates of the reference points in the local laser system. With the knowledge of $[X_i]$ and $[X_{i'}]$, we can use equation (1) to determine [T] and $[X_{o'}]$. With all scanning parameters identified, we can calculate the scanning coordinates of any scan point and finally the scanning voltages.

3D-Alignment: Setup

Let's consider a car door as measurement object whose geometry is represented in figure 2.

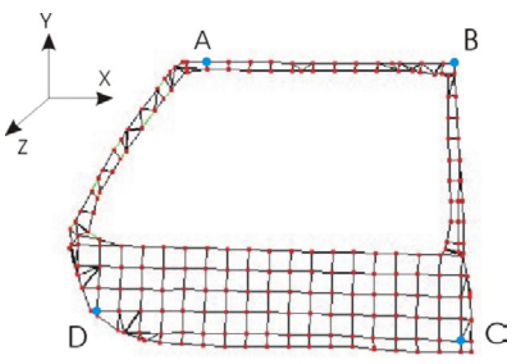

Fig. 2: Measurement grid on a car door

At first you have to select and mark on the structure at least 4 (maximal 7) alignment points whose coordinate description is known in the global system from the geometry file that is to be imported. Those points are displayed by the blue dots within the example. To obtain an optimal measurement result, you have to take care for the following points:

- The alignment points do not have to be in the same plane.
- The alignment points should cover the whole volume of the object.
- The sensor heads should be positioned so that all points are within ± 10° scan angle for all heads

Then you teach the system the scanning angles of each scanning head for each of the reference points by pointing the 3 laser beams successively onto each reference point. The corresponding 3D point coordinates can be entered manually or imported from a file. After assigning the coordinates to the points, the software calculates the alignment and determines the position and the orientation of each head in the global system.

Import

In the 3D point mode, you can now import the scan points from the geometry file. In the contrary way of the point definition via geometric figures, the 3D-coordinates are transformed into the 2D coordinate system of the video image and the mesh is superimposed on the image of the object. The position of the 3 laser beams corresponds to that of the point clicked where the quality of the 2D-alignment leads the lasers beam to come together.

On the other parts (curved surfaces) of the object, the blue nod of the grid and the laser spot do not match exactly. In the 3D point modus, an inaccurate assignment can be readjusted by moving the nod to the corresponding laser spot with the mouse.

When you select one of the scan points, you visually control the quality of the 3D-alignment at the respective point.

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The more precisely the laser beams are superimposed, the greater the quality of the alignment will be. If the average distance among the laser spots is considered as too large in comparison with the size of the structure and the spatial wavelength of the highest shape mode to be investigated, the alignment has to be performed more accurately, or the distance head to object has to be reduced to minimize the effects of scanning angle errors. Disregarding the inaccuracy of the laser point positions can lead to erroneous measurement results.

Pay attention to the fact that the laser cannot reach points on hidden sides. Therefore those points have to be deleted in the geometry file.

Currently the software PSVsoft 8.1 supports Vibrant ME'Scope structural data and Universal File format used by modal analysis software from the companies Vibrant, LMS, SDRC (MTS) and STAR. Please contact Polytec to evaluate the compatibility with another format.

Reference

[1] Yanchu Xu, R.N. Miles: "An identification algorithm for directing the measurement point of scanning laser vibrometers", Optics and Lasers in Engineering 22 (1995) 105-120

If you have specific requirements or need help for you custom solution, please contact Polytec's application engineers.

Polytec GmbH
Polytec-Platz 1-7
76337 Waldbronn
Germany
Tel. + 49 (0) 7243 604-0
Fax + 49 (0) 7243 69944
info@polytec.de

Polytec France S.A.S.
32 rue Délizy
93694 Pantin Cedex
Tel. + 33 (0) 1 48 10 39 3 0
Fax + 33 (0) 1 48 10 09 66
info@polytec.fr

Polytec Ltd.
(Great Britain)
Lambda House, Batford Mill
Harpenden, Herts AL5 5BZ
Tel. + 44 (0) 1582 711670
Fax + 44 (0) 1582 712084
info@polytec-ltd.co.uk

Polytec Japan
Hakusan High Tech Park
1-18-2 Hakusan, Midori-ku
Yokohama-shi, 226-0006
Kanagawa-ken
Tel. +81 (0) 45 938-4960
Fax +81 (0) 45 938-4961
info@polytec.co.jp

Polytec, Inc. (USA)
North American Headquarters
1342 Bell Avenue, Suite 3-A
Tustin, CA 92780
Tel. +1 714 850 1835
Fax +1 714 850 1831
info@polytec.com

Midwest Office
3915 Research Park Dr.
Suite A-12
Ann Arbor, MI 48108
Tel. +1 734 662 4900
Fax +1 734 662 4451

East Coast Office
25 South Street, Suite A
Hopkinton, MA 01748
Tel. +1 508 544 1224
Fax +1 508 544 1225