Practice Report

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Leica Axyz – an Industrial Measurement Software
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Abstract
Industrial measurement tasks are varying. They range from easy tasks to extremely complex tasks. However, one major requirement for a measurement system, consisting of software and at least one sensor, is to solve the measurement tasks with the highest efficiency. Depending on the measurement task different sensors might be required such as a laser tracker and total station for polar measurements or theodolite and Videogrammetry systems for triangulation measurements. The user prefers to work with a limited number of different software packages. Ultimately he would like to have one single software platform which is able to control different sensors. Thus, he could always work with a familiar software independent of which sensor is used. The Axyz concept was designed to meet the requirements of many industries. All Leica sensors (laser tracker and theodolites) are controlled by one software platform. While Axyz offers a comprehensive functionality for solving complex measurement tasks, OLE Automation (Object Linking and Embedding), which comes with Axyz, offers in addition the creation of streamlined software adapted to special measurement tasks.

Introduction
Industrial measurement systems consist, in general, of one or multiple sensors and a software package for controlling the sensors and analyzing the collected 3D data. The more complex a measurement task, the more functionality a measurement software must provide (Fig. 1a). It is also obvious that an user who wants to use the entire functionality of an industrial measurement software package needs more experience than a user who needs just to solve a single, non-complex measurement task (Fig. 1b). Leica’s Axyz industrial measurement software was designed to offer a comprehensive functionality for a wide field of applications. On one hand Axyz CDM, the Core Data Module of Axyz, offers tools for nearly every type of geometrical analysis. Axyz CAD, an additional module, provides all sorts of analysis tools for the comparison of CAD and measurement data and is also a graphical data visualization tool. All Leica sensors such as laser trackers and theodolites are supported by the Axyz software platform. Leica laser trackers are controlled by the Axyz LTM module, multiple theodolite systems by Axyz MTM and single theodolites systems by Axyz STM. Thus, if a user has laser trackers and as well theodolites from Leica, the operators need only be trained on one software platform which reduces training costs dramatically. However, there might be applications which require only a limited functionality from Axyz. For example, in cases in which a single clearly pre-defined measurement task has to be repeated from time to time. In these cases Axyz offers, with its OLE Automation (Object Linking and Embedding), the possibility of creating customized scripts (programs) [Warren 1997].

A script is a streamlined procedure which uses only the functionality required for the special measurement task and guides the operator through the entire measurement process. Thus even an inexperienced operator can easily be guided through complex measurements.

Axyz CDM – Core Data Module
The Core Data Module of Axyz is the heart of the Axyz package. This module offers comprehensive analysis and transformation tools besides measurement configuration, import/export functions and report generation. Some examples of the analysis and transformation tools will be explained in the following.

Fig. 1: The complexity of measurement task and its influence on the required functionality of a measurement software and the experience of operators.

Fig. 2: Axyz comprehensive functionality solves complex measurement tasks. Streamlined software such as an Axyz Script reduces the necessary experience of operators.

[Warren 1997]
Geometric analysis

Axyz offers a comprehensive range of geometrical analysis functions for all sorts of applications.

If symmetry checks are needed it is necessary to calculate geometrical elements such as lines, planes, circles, cylinders etc. (Fig. 3 and 4) by using measured points as the entry data. The geometrical elements are, in general, stored with a local origin and local axes and in most cases with an additional parameter. For example, a 3D circle has a local origin at its center, local axes defined by its orientation in space and a radius.

For inspection during antenna manufacture, CDM enables determination of the geometrical parameters of a parabolic antenna (Fig. 5).

Often it is not possible to measure geometrical features directly because they are not physically defined or not visible. For example, if an invisible intersection point between two pipes is to be determined (Fig. 6), the measurement would proceed as follows. In a first step points on the surface of the two pipes would be measured and their axes would be derived from the geometrical cylinder analysis. An intersection of both axes would lead to the required intersection point and intersection offset (Fig. 6). Other geometrical features can also be determined, such as intersection lines between two planes etc. (Fig. 7).

Additional functionality enables the creation of bisecting elements such as center points, and bisecting lines or planes. They can be calculated for various combinations of elements, e.g. point to plane (result is point), plane to plane (result is plane) etc. (Fig. 8).
Yet more functions based on perpendiculars are implemented which enable the determination of perpendicular distances between points, perpendicular elements such as points to plane, point to cylinder etc. and perpendicular distances between lines which results in either the shortest distance between two non intersecting lines or the distance between two parallel lines (Fig. 9).

A variety of other functions are implemented and are described in the Leica’s software documentation [Leica 1997].

**Transformation**

Transformations are needed for applications requiring special coordinate systems (Fig. 10). Many applications need to analyze measurements in the object coordinate system such as aircraft system, car system etc. Especially in build mode, where an operator must, for example, position parts in a jig, it is very helpful to create local coordinate systems to better visualize the directions of movement which are determined by the measurement system.

Axyz offers not only comprehensive and comfortable transformation tools such as 3D-transformation, translation, rotation, scaling and 3-2-1 transformation but also an easy management tool for the different coordinate systems. All coordinate systems are stored in the data base and all measurement data in job can be visualized in the required coordinate system by mouse click.

**Axyz CAD - CAD Comparison and Visualization**

Axyz CAD is a graphical module for displaying measurement data and analysis data both off-line and on-line. It also offers tools for the comparison of CAD data with measured data. Once the CAD data, which usually represent design data, are imported via IGES, VDAFS or DXF format, the comparison with measurement data can be performed. It is therefore possible to inspect freeform surfaces on-line, i.e. immediately after points on a surface were measured with a theodolite or laser tracker system, or in the off-line mode, i.e. during post-processing after all measurement data were collected. The results of the comparison can be displayed in either numerical form (Fig. 11) or in graphical form as needle plots or color maps (Fig. 12a and b).
Axyz LTM - Laser Tracker Module

The Axyz LTM controls laser trackers (Fig. 13) which are based purely on interferometric distance measurement, such as Smart 310 and LT500, as well as trackers with integrated absolute distance measurement such as Smart 310 with ADM (Absolute Distance Meter) and LTD500.

Using interferometric measurement, up to 1000 points per second can be collected. This measurement mode, the so-called continuous measurement mode, is specially suitable for digitizing surfaces, either for reengineering parts or inspecting surfaces. Measurements of dynamic processes such as robot movements are also possible.

The built-in, high-precision absolute distance meter (ADM) is used to lock onto the reflector again if the interferometer beam is broken during object scanning. The ADM additionally provides a very powerful measurement mode known as auto-inspection. Auto-inspection enables fully automatic, sequential point measurement to be made with extremely high accuracy. If nominal coordinates of the measurement points are already known, for example in a repeat measurement, the laser tracker quickly acquires, measures and compares each measured point to its existing or design values and displays any deviation. This powerful measurement mode has many uses, for example the automated inspection of tooling jigs. With the newly developed CCD viewfinder the operator has an extremely useful support tool. For example, if a measurement fails during auto-inspection the monitor of the CCD viewfinder displays the area where the reflector should be. This is particularly useful for points distant from the laser tracker. The operator can easily determine whether the initial coordinates were not accurate enough or if the reflector was not placed on the point to be measured.

To aid recognition, flashing illumination causes the reflector image to blink on the screen (Fig. 14). The reflector can therefore be easily identified within its environment.

Axyz MTM & STM - Multiple & Single Theodolite Modules

With its Axyz STM and MTM modules, Axyz supports Leica theodolites. STM is the module for single theodolite systems and MTM for multiple theodolite systems. While STM supports Leica polar measurement theodolites such as TC2002, TPS 5000 (TDM/TDA types) (Fig. 15), TPS 1000 (TC/TCM/TCA types), the Axyz MTM also supports the triangulation theodolites T(C)2002, T3000, T3000A, T(C)2000, E2, E2-I, E20, E20-I, TPS5000 (TM as well as TDM, TDA types) (Fig. 16) and TPS1000 (with AxyzComm). The new motorized generation in particular offers significantly improved efficiency because these theodolites can, for example, be automatically positioned in inspect mode using initial coordinate values.
Axyz Scripts - OLE Automation
As outlined by D. Warren, 1997, Axyz can be customized through scripting. Since Axyz software has exposed many of its functions or objects to OLE automation it is possible to write Microsoft Visual Basic scripts which include original Axyz functions. Two classes of scripts make use of high and low level OLE functions (Fig. 17). Scripts with high level OLE functions guide the operator through a predefined process in which the operator must go through dialogs interactively. Scripts with low level OLE functions perform processes fully automatically. This means that after starting the script no interaction by the operator is required. High level functions are particularly needed in cases where the process cannot be 100% predefined and automated so that the operator can react to the requirements of certain measurement tasks. Many applications can use the scripting technique to automate the measurement process, for example joining major aircraft components, monitoring flexing during modification, or coordinating the position of robot end effectors [Warren 1998].

Literature

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