Semi-automated analysis tool for survey system using photogrammetry

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Photogrammetry is a technique to reconstruct three-dimensional geometry by photographing an object from various angles. An alignment of experimental equipment in RIBF has often been surveyed using a laser tracker system in the installation period and the photogrammetry system V-STARS (Geodetic Systems Inc.) after relocation for each experiment.[1)]

The V-STARS is one of the commercial toolkits including devices and software for photogrammetry. The system provides TARGET marker positions attached to an object, represented as a reflective circle surrounded by a thick black circle, as shown in Fig. 1.

The TARGET marker positions in 3D coordinate are evaluated from the multiple photographs involving several CODEs, which feature seven or eight reflective circles on a black square sheet. The system automatically employs an arbitral axis in 3D. After obtaining the 3D position information of TARGET markers in an arbitrary coordinate system, many manual operations are necessary to convert the coordinates from the arbitral frame to the laboratory frame.

The typical positioning accuracy achieved in RIBF to date has been several hundred micrometers, although it has occasionally reached a few millimeters. During the operation, mismatching the TARGET markers, which means the system misidentifies different markers as the same or the same marker as a different one, brings a large position error. Corrections need to be made manually, which can lead to human errors, making it nearly impossible to trace back.

We developed two types of analysis tools for user-friendly usage, as part of RIKEN TRIP initiative (Use-case: Nuclear Transmutation). One is a script utilizing V-Script, included in the V-STARS package. The V-Script-based tool enables semi-automatic analysis: calculating 3D vectors (so-called "Bundle"), correlating the coordinates using marker-position design files, and recording operating logs.

The other tool is a python script with functionality not included in the product:

(1) transformation of the coordinates without requiring a V-STARS license,
(2) coordinates of special virtual position such as the center of a detector without marker pasting,
(3) human-understandable transformation representations such as rotation angles,
(4) logging of operation details at every step, and
(5) error values caused by rotation, based on a clear rotation algorithm (to be implemented).

In the V-STARS system, the transformation parameters are provided along with the rotation matrix M and the vector of parallel shift S with the equation $B = CM(A - S)$, where B and A represent the vectors of a marker before and after transformation, respectively. The vectors S, B, and A are denoted by its $(\mathrm{x}, \mathrm{y}, \mathrm{z})$ components. In the developed tool, we also performed transformation using the rotation matrix and parallel shift. We utilized the SciPy module to calculate the transformation and convert the rotation matrix to rotation angles.

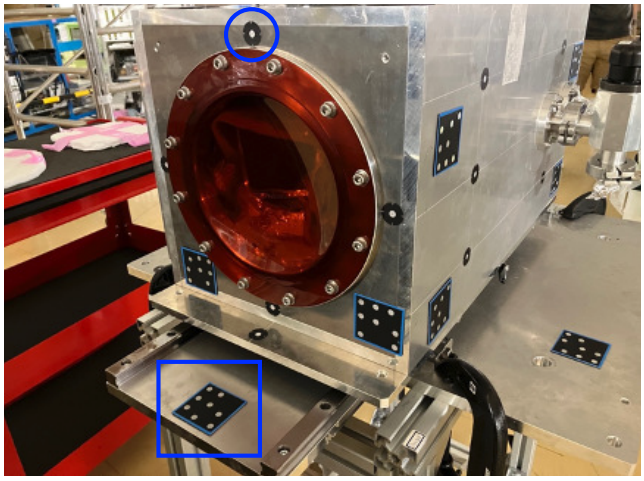

Fig. 1. Photograph of the markers attached to the device, with one TARGET (18 mm in diameter, circled) and CODE (approximately 50 mm square, boxed) highlighted. TARGETs attached to the hairline are an idea to indicate the reference positions of the device.

As the default rotation angles, we provided Tait-Bryan with extrinsic rotations in the Z-X-Y order. This is because survey systems generally use extrinsic perpendicular coordinates. The reason for selecting the Z-X-Y order is to minimize two transformation angles Z and X. The method only Y angle can be large is well-suited to many beamlines because of the orientation of the magnetic field and the positioning of the equipment.

We compared several rotation algorithms to determine the most appropriate method for handling asymmetric errors in real survey environments. As a prospect, the propagated error values are provided with public algorithm. With this tool, any analysts can later transform the coordinates with human-understandable rotation parameters. The results are more intuitive and easier to verify.

Reference

1) https://www.geodetic.com/v-stars.

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