correlated SOLUTIONS

Application Note

Coordinate System Registration and Stitching Using Markers with Known Locations

VIC-3D 9

2021

Coordinate System Registration and Stitching Using Markers with Known Locations

Overview

In this application, digital image correlation (DIC) data is acquired from multiple, rigidly-mounted stereo (2-camera) systems. The systems are initially calibrated as separate; then, a registration is performed using fiducial markers with known coordinates on a calibrated object. This registration is used to transform the Cartesian coordinates of each camera in each system to its known location in 3D space; then, all following DIC data will be in this known Cartesian system so that the data from every system will be placed consistently. This data can be examined independently or combined for 3D visualization.

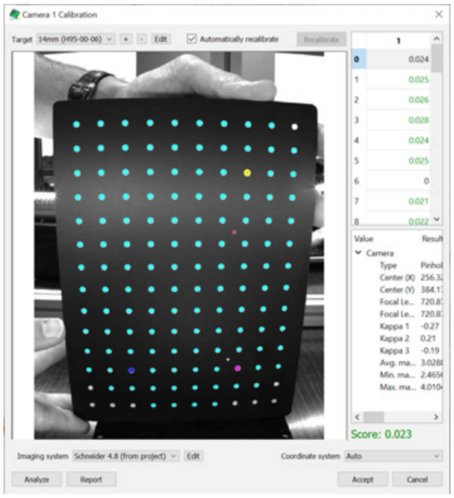
Stereo Calibration

The stereo calibration step is exactly as typical for a large-scale stereo DIC configuration. Images are taken of a rigid grid in various poses, in each camera, and each camera is calibrated separately for its intrinsic parameters.

Begin calibrating each system by taking calibration grid images, choosing a grid that nearly fills the field of view. With short lenses, a fairly small grid (20 mm or 28 mm) may be used to image very large fields. For each camera, take 30-40 images with good tilts in all 3 axes (top-bottom, left-right, and spinning in-plane). Because the lenses used for large scale calibration are typically short, more images are needed for a very accurate calibration of high-order distortions.

After acquiring the grid images, acquire a single static image of the speckled test specimen. This will be used later for orientation calibration.

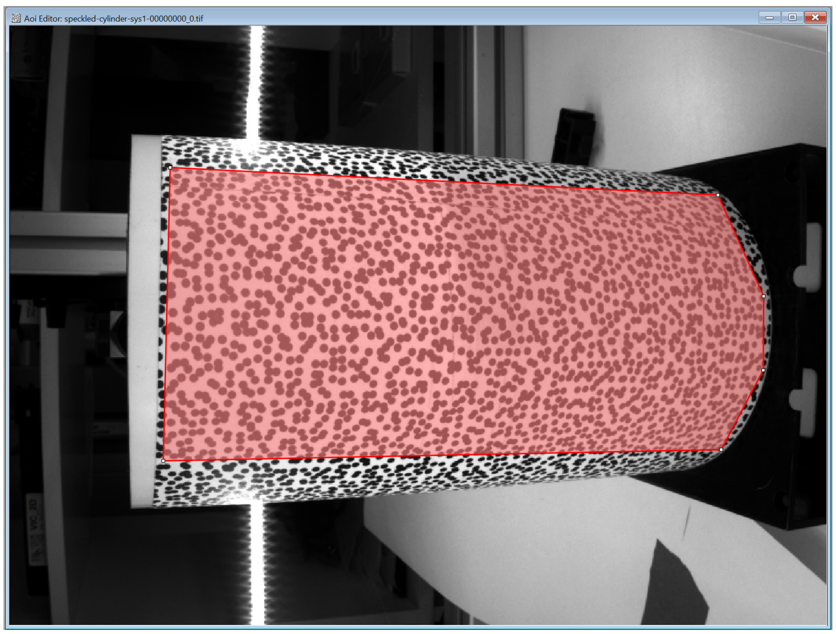
Next, start VIC-3D and add the relevant images. Click *Calibrate... Calibrate Camera 1* to calibrate the first camera. The points should extract automatically, and a score will be reported.



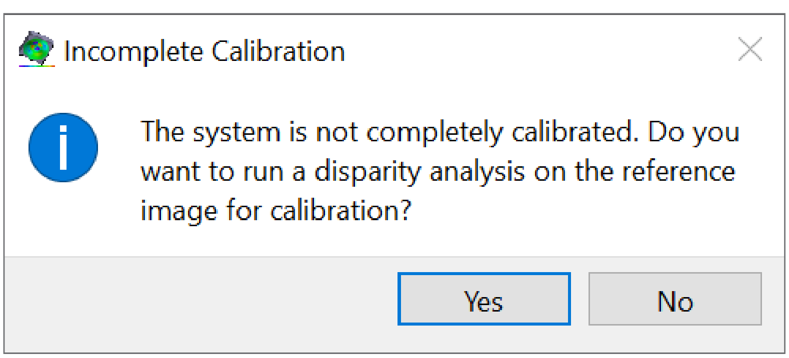
The score should be very low (<<1); if it is high or red, check for bad images, occlusions from fixtures, etc. Otherwise, click **Accept**.

Repeat this process with *Calibrate... Calibrate Camera 2*. At this point, the cameras are calibrated individually, but the stereo rig is unknown.

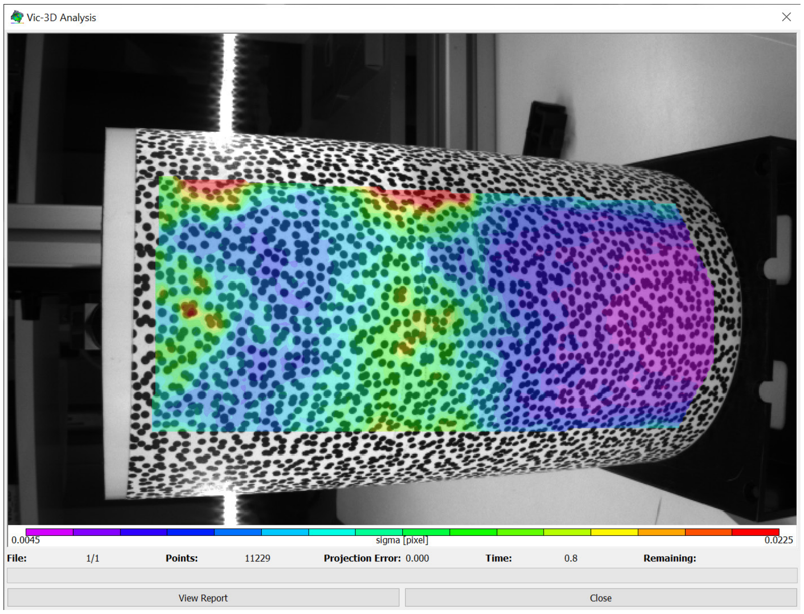
Add the static image of the speckled reference (*Project... Speckle images*), and draw an AOI over the speckled area. The area should be as large as possible and should not be close to colinear. Multiple AOI's may be used.



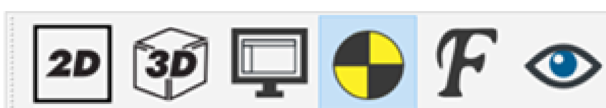
Click **Start Analysis**. You will be warned that a calibration is not present – the resulting analysis will give a *disparity* field but not a 3D result because triangulation is impossible at this stage.



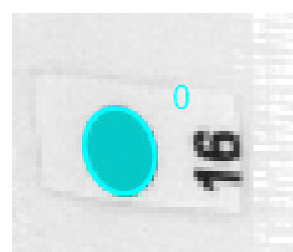
After running the analysis, the disparity result will be shown. If no points were analyzed or if part of the AOI is missing, it may be necessary to add an initial guess (using the AOI tools) and retry.



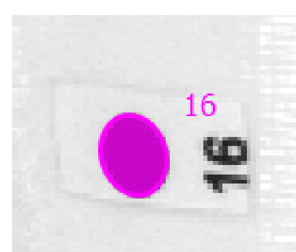
To complete the extrinsic calibration, a very accurate distance in the field must be known. This is best accomplished using the existing markers. Click the *Marker Editor Workspace* button in the main toolbar to enter the Marker workspace:

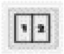
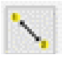


The static image will be displayed. Then, for at exactly two visible markers, click the marker in the image view. A marker overlay should snap to the displayed marker and match the shape and size; if it does not appear or appears incorrect, you may need to adjust the *Maximum size* to be equal to or greater than the size of the marker, in pixels.



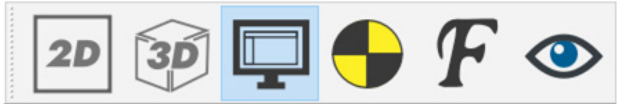
Next, click in the *Label* field and enter a label which matches the marker's label. Repeat this for the other marker.



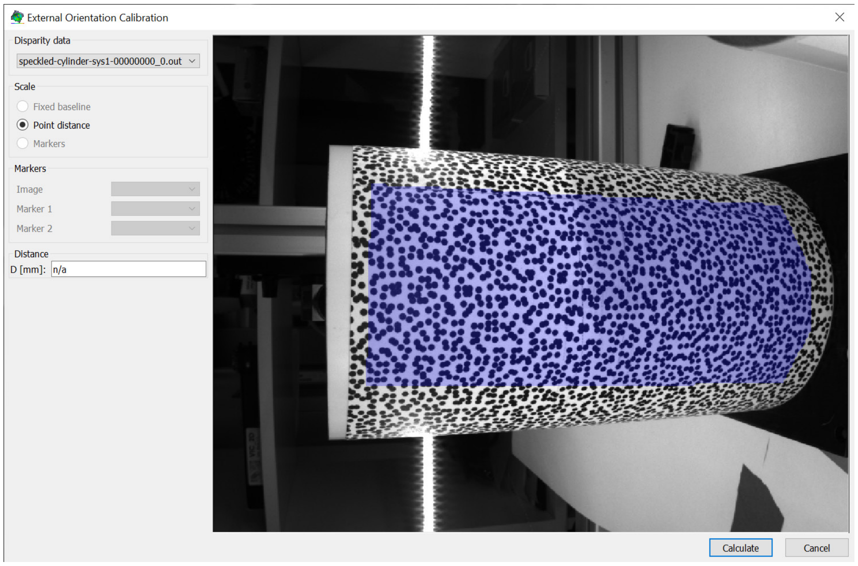
Next, both markers must be associated with the other camera's view. Click the  button in the tracking tools to see the images side by side. Next, click the  button to begin association.

For each marker, click the marker in the left image, and then click the corresponding marker in the right image. Confirm that each marker snaps and looks correct, as with the initial placement.

These two markers will be used to establish a length baseline. To complete calibration, click the **Main workspace** button to return to the DIC workspace.

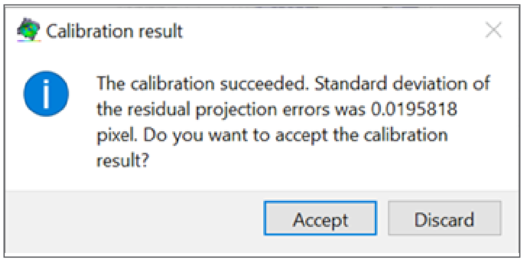


Click *Calibrate... Calibrate camera orientation* from the main menu.



Since we will be using marker information for the baseline, click the **Markers** radio button. Select the two markers and enter the known distance between them in mm in the **Distance** line editor. This is the resultant distance in 3D space between the two markers irrespective of the curvature/shape of the object.

Click **Calculate** to see a result and error score:



The score should be very low (less than 0.1). Click **Accept** to complete system calibration and save the project.

Each system should be calibrated independently and then the calibration file saved with a consistent name (for example, *sys1-cal.z3d*, etc.) Saving intermediate files at each step will make it much easier to diagnose and correct any procedural problems that should arise.

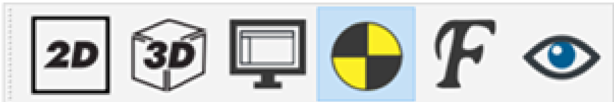
Marker Registration

This step requires a test object with at least **three** markers visible to **every** system (3 * n_systems total). The markers may be elliptical or quadrant markers, and in either case the center of the marker must have known coordinates in real space. This process is much more practical if every marker is independently visibly labeled with an adjoining name.

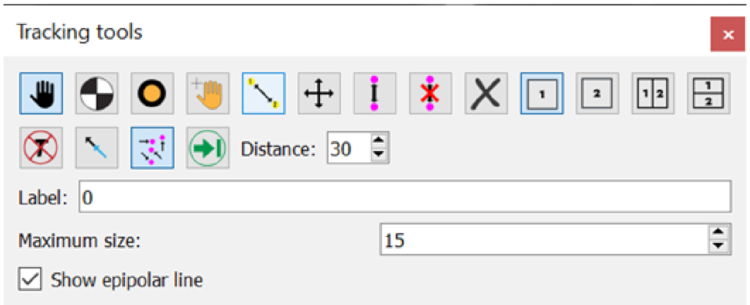
The registration begins by taking an image simultaneously, in all systems, of the test object. Then, each stereo system will be treated independently.

Begin by taking the registration image; it is best to use a readily recognizable filename such as *registration* or similar. This could be the same image used for the orientation calibration, or a new one. Next, for each stereo system, begin by loading the calibration project saved in the previous step (E.g., *sys1-cal.z3d*). Then, using *Project... Speckle Images*, add the matching image file. It's critical that the *sys1* file be used with the *sys1* calibration, *sys2 for sys2*, etc. You can save the project at this step with a filename such as *sys1-markers.z3d* or similar.

Click the **Marker Editor Workspace** button in the main toolbar to enter the Marker workspace:



Click the relevant marker type in the **Tracking Tools** at the top left (quadrant or ellipse):



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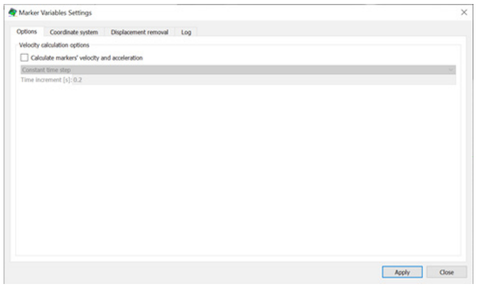
Then, for at least three visible markers (more may be used for error reduction), click the marker in the image view. A marker overlay should snap to the displayed marker and match the shape and size; if it does not appear or appears incorrect, you may need to adjust the *Maximum* size to be equal to or greater than the size of the marker, in pixels.

Next, click in the *Label* field and enter a label which matches the marker's label. This will make associating the marker with its known coordinate much simpler and more error proof.

Repeat this for each marker (click, **enter label**).

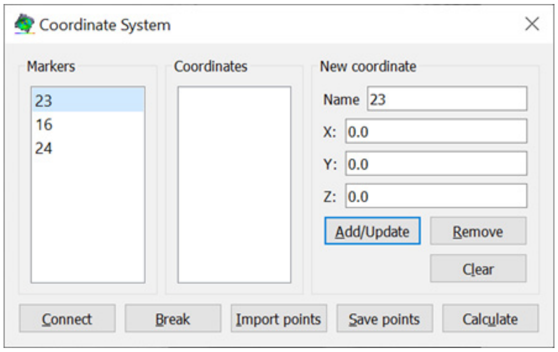
Next, the markers must be associated with the other camera's view. Click the button in the tracking tools to see the images side by side. Next, click the button to begin association. For each marker, click the marker in the left image, and then click the corresponding marker in the right image. The marker can be more easily identified because it should be on the green epipolar line. Confirm that each marker snaps and looks correct, as with the initial placement.

Next, the markers must be triangulated into 3D positions. Click the button in the Tracking tools:

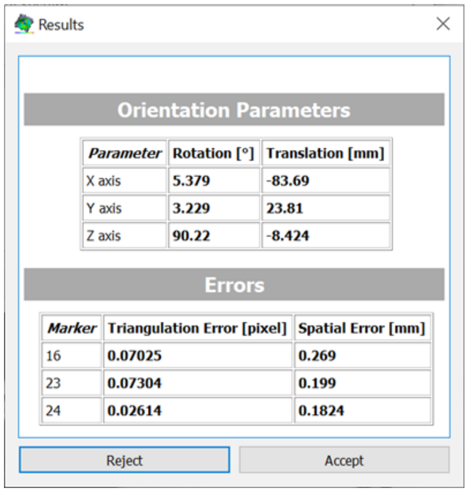


Clear the *Calculate markers' velocity and acceleration* button to avoid warning messages, since only one image is present. Then, click **Apply**. A brief log message will appear; click **Close** to complete.

Now that the 3D locations of the markers are known, we can associate them with the known fiducial locations and construct the new Cartesian system. Click *Data... Markers... Coordinate system fit* from the main menu.

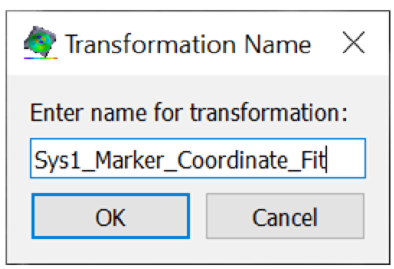


Next, click **Import points** and select the CSV file containing the known point locations. As long as the markers have all been correctly named, they should be automatically associated, and the following dialog will appear:



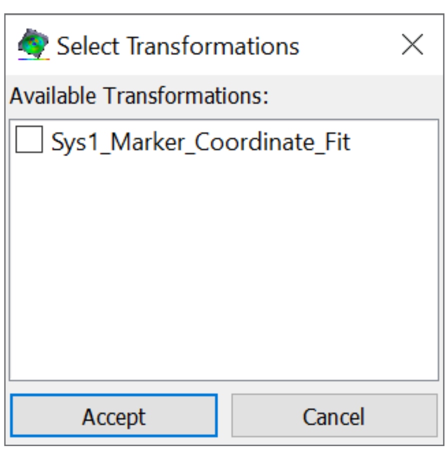
Click **Yes**, then **Calculate**. A result display will appear. Both the Triangulation and Spatial error should be low (<<1); if any are particularly high, the marker may have been extracted incorrectly, or a marker may be named incorrectly, or a physical coordinate measured incorrectly.

Otherwise, click **Accept**:



Enter a meaningful name for the transformation and click **OK**.

Finally, click *Data... Coordinate Tools... Set Coordinate System* from the main menu.



Select the transform from the step above and click **Accept**. The internal camera locations should now match their actual coordinates in real 3D space, so that future correlation with this calibration will give results in a consistent and real Cartesian coordinate system. With this done, save the project with a meaningful name (*sys1-final-cal* or etc.).

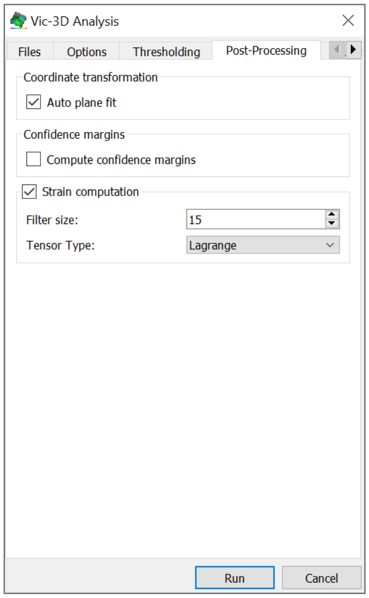
This process must be repeated for each system. Then, as long as the cameras do not move, the calibrations will be valid.

Running the Correlation

Now, for each stereo system, correlation will proceed in a typical fashion. First, test that the registrations are correct by taking a static image of the final test specimen – give this a meaningful name such as static.

For each system, import the calibration from the final step above using *Calibration... From project file* from the main menu, and select the appropriate final calibration file.

Next, draw an AOI as usual. Click **Start Analysis** and be sure that Auto Plane-Fit is **off**:



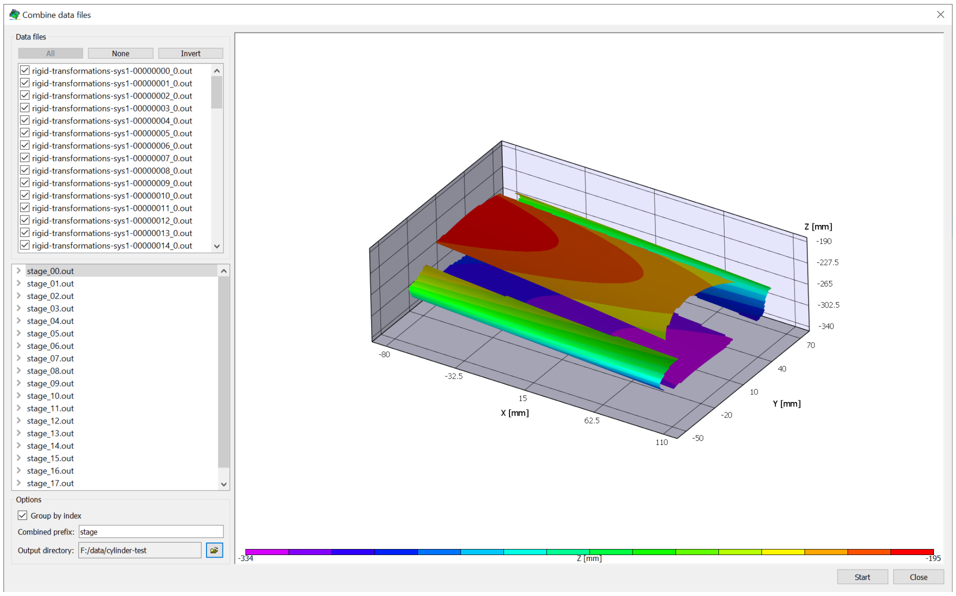
This will ensure that our results are in the real Cartesian system we established earlier and not a new and inconsistent auto plane fit system.

Run the data. The XYZ coordinates should be sensible and the right, left, or rear of the object may be displayed depending on how the systems are arranged:

Repeat this for each system present.

Finally, to check the fit, start a **New project**. Next, click *Project... Data files* from the main menu and add all the data files from the previous step.

Click *Data... Postprocessing tools... Combine data files* from the main menu:



Click the **stage** file at the lower left to see a preview. The plot should be sensible and form a full 3D shape. You may also change the prefix to something other than *stage* if desired.

If the data looks nonsensical (overlapping incorrectly, one AOI is in an inconsistent coordinate system, etc), it will be necessary to go back through the process for the given AOI (or all of them) and double check that:

- Auto plane-fit was off at analysis time
- The registration markers were selected and labeled correctly
- The correct coordinate system was set during the *Data... Set Coordinate System* step
- The correct static speckle image for each calibration was used

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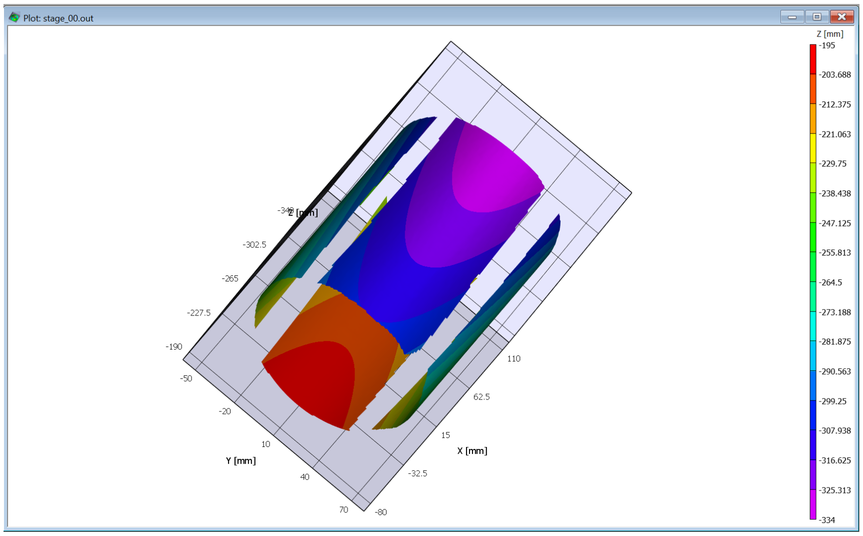
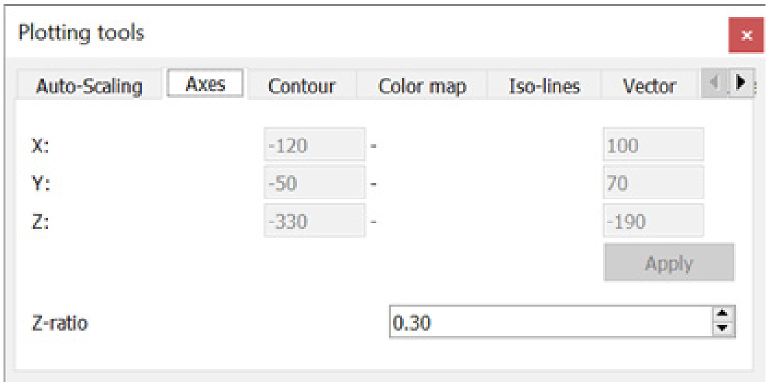
Click **Start** to generate the new data file and add it to the current project.



The new data file contains all four AOI's. Note that it cannot be viewed in 2D because it is not associated with a single TIF. Also, cylinders may not look properly cylindrical without adjusting the Z-ratio in the Plotting Tools:



If everything looks right at this point, we can proceed with dynamic tests.

Dynamic Testing

Once the system is calibrated, the cameras should not move or be adjusted, either within or between stereo rigs. Synchronized images for all systems should be acquired for the duration of the test.

Then, to process each data set, start VIC-3D and use *Calibration... From project file* to import the final calibration used in the prior step. Add speckle images from the dynamic test; draw the AOI(s); and run the analysis.

This should be repeated for all systems. Then, start a new project, and add the output files from all systems. Click *Data... Postprocessing Tools... Combine data files*, and check that the combined files look correct. Then select a proper output prefix and click **Start**. A new *stage* (or other selected name) file will be created for each set of input data files.

Support

If you have any questions about this document or any other questions, comments, or concerns about our software, please contact us at support@correlatedsolutions.com, or visit our website at support.correlatedsolutions.com.