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Title: DARHT Radiographic Grid Scale Correction

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Introduction

Recently it became apparent that the radiographic grid which has been used to calibrate the dimensional scale of DARHT radiographs was not centered at the location where the objects have been centered. This offset produced an error of 0.188% in the dimensional scaling of the radiographic images processed using the assumption that the grid and objects had the same center. This paper will show the derivation of the scaling correction, explain how new radiographs are being processed to account for the difference in location, and provide the details of how to correct radiographic image processed with the erroneous scale factor.

Background

The drawings in Figure 1 show how various plate radiographic targets are held in place at DARHT. The normal location for the targets, using the existing bracket, is upstream (toward the source) of the center of the object such the downstream target face is located at the object center.

Figure 1 The DARHT aligning support and bracket used to accurately locate the plate radiographic targets.

The targets are 5 mm thick, therefore the target center is located half the thickness, 2.5 mm, toward the source from the center of the object center.

The target used to calibrate the DARHT radiographs, the radiographic grid, has two interleaved grids of crosses each with spacing between the crosses of 1.0 cm. A photograph of the radiographic grid target is shown in Figure 2.

Figure 2 Photograph of the radiographic grid used to determine the dimensional scaling of DARHT radiographs.

The preprocessing of DARHT radiographs includes a step during which the radiographic images are dewarped and dimensionally scaled. The preprocessing software uses the IDL routine POLYWARP to calculate the least-squares fit that will scale and dewarp the crosses in the image of the radiographic grid onto a uniformly spaced grid. Then, the IDL function POLY_2D is used to apply the dewarping function to the DARHT radiographs. The preprocessing software allows the user to specify the spacing of the uniform grid.

Figure 3 The value necessary to calculate the effective grid spacing is the magnification from the center of the radiographic grid location to the center of the object location.

Originally the default value for the grid spacing was 1.0 cm. Now the effective spacing is 1.001883 to take into account that the radiographic grid is located 2.5 cm toward the source. Figure 3 shows the equation of the effective grid spacing, given a DARHT source-to-object distance of 133.0 cm. Also shown is the window from the preprocessing software where the correct effective grid spacing can now be selected.

The reason for locating the radiographic grid at the object location is to eliminate the need to accurately measure the source-to-object and source-to-detector distances. Even when the grid is not located at the object, scaling the radiographs to the object location does remove the source-to-detector distance from the calculation. But, with the object and grid at different locations, uncertainty in the source-to-object distance increases the uncertainty in the determination of the effective grid spacing correction. However for the geometry at DARHT, this uncertainty is negligible. Figure 4 shows a plot of the effective grid spacing correction for a source-to-object distance range of 133.0 ± 2 cm.

Figure 4 For fairly large uncertainty in the DARHT source-to-object distance, the variation of the effective grid spacing is very small.

For DARHT, the radius of the maximum field of view at the object is about 5.7 cm. Failing to correct for the actual location of the radiographic grid would produce a radial error of about 107 microns for the nominal source-to-object distance of 133.0 cm. If the actual source-to-object distance was off by as much as ± 2 cm, the radial error at the maximum radius would only change ± 2 microns.

Check of the Effective Spacing Calculation

A model of the radiographic grid has been made using new 3D tools in the Bayes Inference Engine (BIE). Two radiographic images of a DARHT Axis 1 radiograph (having 4.7625 cm of tungsten based alloy in the bullnose) have been modeled two ways. One radiographic image is the result of preprocessing using a grid spacing of 1.0 cm and the other was preprocessed using a grid spacing of 1.00883 cm. Each image was modeled using a grid location of 133.0 and 132.75 cm (in both cases the source-to-object distance was 133.0 cm). Examples of the DARHT radiograph, the BIE forward model radiograph, and the residual image (difference between the data radiograph and the forward model) is shown in Figure 5.

Figure 5 Examples of the DARHT radiographic grid and BIE forward model radiographs. The residual image is the difference between the data radiograph and the forward model radiograph.

The images have 100x100 micron pixels. For each case an optimizable scale was applied to the DARHT radiographic image and an optimizable system blur function was convolved with the forward model. The resulting optimizable scale factors and system blur parameters are shown in Table 1.

Table 1 Results of varying the effective grid spacing during preprocessing and varying the BIE grid model center location

Grid Space (cm)	Model Offset (cm)	Model Center (cm)	Optimized Scale	Scale Should Be	Scale Error %	Error at 5.7 cm (microns)
1.001883	-0.25	132.75	0.999442	1.000000	-0.056%	-31.8
1.001883	0.00	133.00	0.998351	0.998121	0.023%	13.2
1.000000	-0.25	132.75	1.001813	1.001883	-0.007%	-4.0
1.000000	0.00	133.00	1.000665	1.000000	0.066%	37.9

System Blur Bennett Scale X (cm)	System Blur Bennett Scale Y (cm)	System Blur Rotation (degrees)
0.0368	0.0379	7.72
0.0369	0.0380	7.72
0.0373	0.0379	7.73
0.0368	0.0378	7.72

Correction for Existing Radiographs

To correct the dimensional scaling of a DARHT radiograph that was dewarped and scaled assuming an effective grid spacing of 1.0 cm just scale the radiograph by 1.001883. Then the radiograph will be magnified correctly for an object located at 133.0 cm from the source. However, after a radiographic plate target radiograph has been corrected, it is necessary to model the target correctly. All of the plate targets (the Air Force target, the circular resolution target, and the radiographic grid) have the same center location (2.5 mm upstream of the object center). For 2D image models of a plate target, the image can be scaled by 1.001883. For 3D models, just locate the center of the plate target at the proper location (132.75 cm from the source).

Conclusions

DARHT radiographs can be preprocessed correctly taking into account the grid-to-object offset without having to know the DARHT source-to-object location (133.0cm) to better than several centimeters.

DARHT radiographs that have already been preprocessed using the assumption that the grid-to-object offset was zero can be corrected by scaling the radiographic images by 1.001883. Radiographs that are not corrected will have a radial error that varies from zero at the center of the image to about 107 microns at the edge of the field of view.

New plate target brackets are being designed to locate the center of the plate radiographic targets at the object center. These new brackets will eliminate any need to accurately measure the source-to-object distance and allow the actual grid spacing of 1.0 cm to be used during the preprocessing of the radiographs.