

Instructions for using the two 3D capture processes

First Method

Item and apparatus setup

The following list highlights key attributes of the setup process:

1. Height of item
2. Position of item under the glass platform
3. Height of aperture lights
4. Height of mask lights
5. Width of aperture
6. Camera position and focus

1. Height of item

The item needs to be as close to the underside of the apparatus glass as possible in order to optimize the effect of the structured light cast through the aperture mask. However, do not allow the item to touch the bottom of the glass as this will cause the item to move when the apparatus changes angle during capture of the section images. Moving the item, camera, or refocusing during capture of the section images causes them to no longer be registered to one another, and the resulting composite displacement map will be of very low quality or unusable.

2. Position of item under the glass platform

Place the item under the glass platform and slide the aperture mask assembly back and forth along the length of the apparatus. For each position of the apparatus the entirety of the item should be viewable through the aperture as the mask assembly is slid back and forth. If some portion of the item to be scanned is not visible at some point during the full gamut movement of the aperture assembly then it will not appear in the final composite.

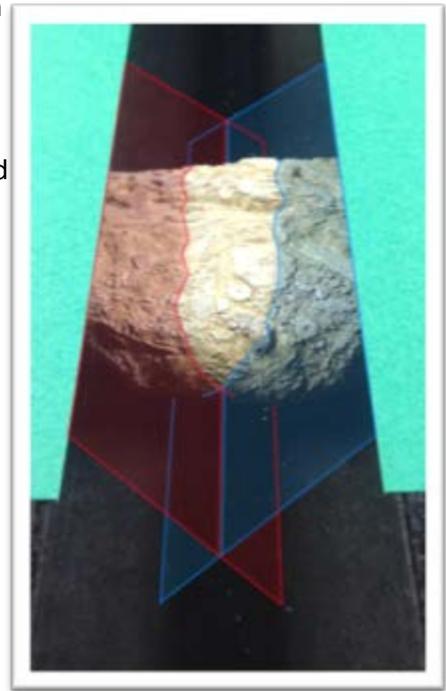
3. Height of aperture lights

Adjusting the relative height of the aperture illuminating lights changes the distance below the surface of the aperture mask where the structured light crosses. Bringing the lights lower down toward the mask surface level makes the effective depth you can illuminate, and therefore digitize, shallower. However, the more parallel the angle of the light is to the surface of the relief the more detail is revealed by the raking light, and this translates into a better quality displacement map.

4. Height of mask lights

The mask-illuminating lights are an optional set of lights helpful when trying to remove the masking from the section images automatically with chroma key processing. To adjust these lights, place them low and wide, slightly higher than the aperture mask level. In this way the light from the mask-illuminating lights will brighten the mask but the angle will be too parallel to the aperture to pass through it and interfere with the illumination of the relief item. Making the mask appear brighter while keeping the item seen through the aperture darker will allow the tones of the mask to be isolated and removed from the section images via script.

1 When adjusted correctly high points on the object are illuminated by both aperture lights: the lowest points under the aperture will be illuminated by neither light



5. Width of aperture

Position the aperture mask assembly over an area of the item with a wide range of difference in relief height. Adjust the width of the aperture while watching the shapes of light and shadow expand and contract as the aperture opens and closes. An optimal width for the aperture creates an equally wide stripe of light on the high areas as shadow on the low areas. Slide the mask assembly back and forth to check that there is consistent modulation of lights and shadows across all high and low areas of the item.

6. Camera position and focus

Position the camera as you would to capture an item in a reprographic fashion. If you plan to use a chroma key process to remove the mask from the section images, make sure to focus the camera on the plane of the aperture mask; otherwise, temporarily remove the mask assembly and focus on the item.

Things to spot check during setup

- Look for any reflections in the glass from lights or equipment. Because the section image composite is a summation of pixel values from all overlapping sections, a very faint reflection can become an out-of-gamut white spot in the final composite.
- Dust, fingerprints, and scratches on the glass will also add up in the section composite, creating pronounced white spots.

Section images capture and processing

The following list highlights key aspects of the section image capture process:

1. Capture section images
2. Capture image for texture map
3. Optimize and export all images

1. Capture section images

Position the apparatus at the first angle position. Slide the aperture mask assembly to one edge of the item so that it is totally covered by the mask. Capture a range of images by shooting an image and then moving the aperture mask assembly across the top of the item. To simplify the capture process and avoid undue complication, the aperture mask assembly was moved by hand at an interval described as “just as much until you can tell it has been moved”.

**During digitization of sample images, 28 section image captures per inch was the recorded average rate.*

Consistency in the interval and complete coverage of the final image area by section image captures is important to achieving best results from the process; if the interval of capture fluctuates this will create light and dark stripes in the displacement map resulting in linear peaks and valleys in the resulting geometry. If there are portions or corners of the item not fully covered by section image captures from every angle, dark corners or areas in the displacement map will occur and a flattening of the resulting geometry for those areas will be the result.

2. Capture image for texture map

Remove the aperture mask assembly from the apparatus to expose a complete view of the item. Texture map images that achieved the most legible results were made by strong lighting from one direction and weaker lighting or ambient room light from the other direction. This means turning off lights from one side of the camera stand and then turning off the apparatus light on the other side. Again, remember all images must be aligned, so take care to not move anything or refocus during any portion of the capture process.

3. Optimize and export all images

For this portion of the process Adobe Photoshop’s Camera Raw was used to optimize all images in batch. Open all section images and texture map files in Camera Raw. Select one of the texture map images as the primary image and then add all remaining images to the selection. Rotate and crop to the entire item as seen in the texture map image. Doing this while all of the section images are also selected

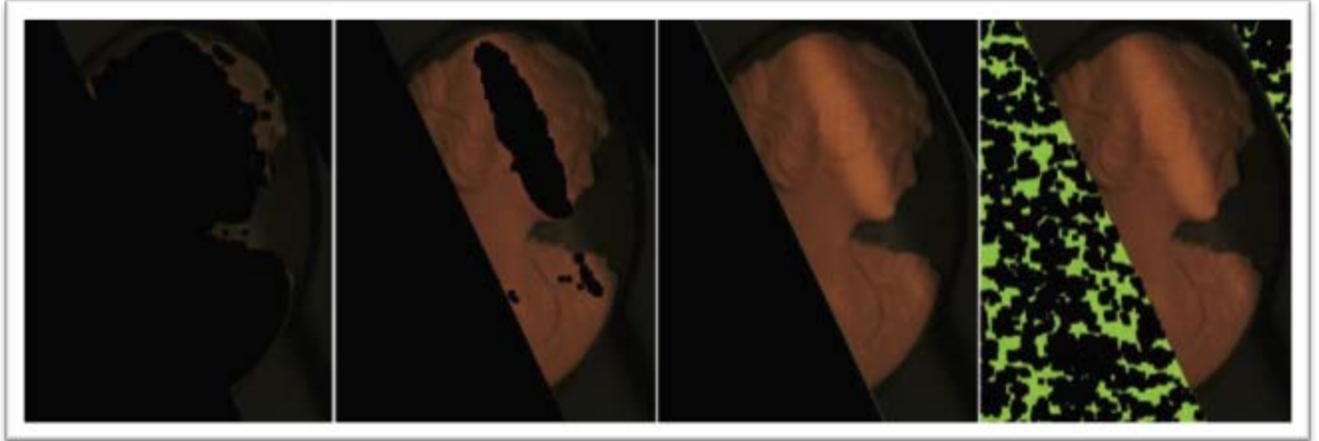
will result in the same crop and alignment edits being applied to all images equally, maintaining registration of all section and texture map images.

With the images all still selected choose “save images” and export a copy of all images as .tif files. Camera Raw allows for a standard reduction in size based on shrinking the files to a common long side pixel length value. Based on computer processor power and available memory, the base size of the section images you can process will vary. During this test using a computer with 3.4Ghz processor and 8 gigabytes of memory, files of up to 1000 pixels on the long side were comfortably processed during all aspects of the procedure. An image was processed at 5000 x 3500 pixels as a stress test; it did finish, though it took 6 hours to render.

Chroma-key processing with Daxelject

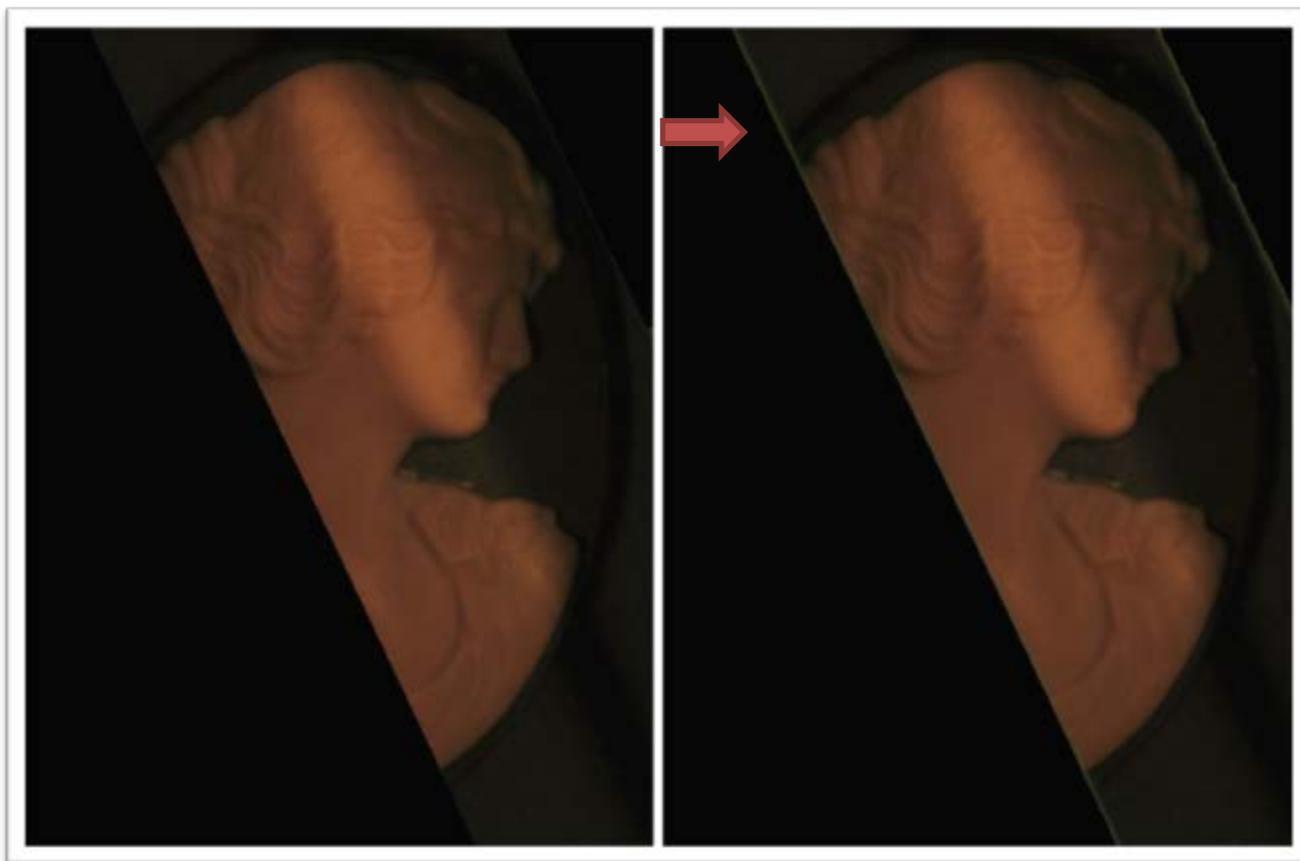
1. Move all section image .tif files to a folder location by themselves. The Daxelject installation comes with a folder located in the root directory named “.\ckr” expressly set aside for holding chroma-key-raw files.
2. Start the Daxelject software and select the “.\ckr” folder by clicking on the “Select chromakey matted files location” button and browsing to the folder.
3. Select the location for processed files to be deposited by clicking the “Select save location for processed files” button and browse to the “.\ckp” folder also located in the Daxelject root folder expressly for the purpose of collecting chroma-key-processed files.
4. Take note of the pixel length and height for the set of section images you are processing. You can get this information by opening one of the files in Photoshop or other image editor or by right-clicking one of the files and selecting “properties”, then “details”, and scrolling down to “image”. Enter the pixel dimension length in the “x” value field, and the pixel dimension height in the “y” value field located on the left hand side of the Daxelject interface.
5. The mask color channel field sets which one of the “r”, “g”, or “b” color channels will be used to detect the mask. The default is “g” because an images green channel, in general, is the most reliable representation of overall image brightness values.
6. The Chroma tolerance % field sets the sensitivity of the color matching process. The number represents the percentage of values, starting from “0” (black), that will remain in the image after the mask has been applied. For instance if 15 percent is the setting the darkest 15 percent of values (from 0 to 255) will be left behind and all of the other 85 percent of lighter values will be masked out and replaced with black. The key to good results with this tool is to have a gap between the darkest values found in the mask and the lightest values seen through the aperture. Finding an optimal setting may take several test runs in order to get it working well.

**Warning: if there is a crossover of values between the mask areas and areas in the aperture you will not be able to isolate the mask without also masking some parts of the subject. This is from a failure to illuminate the green mask enough during capture of the section image.*



2 Here is a single section image that has been chroma-key processed at four different percentage values, there was a gap from 35 percent to 70 percent that achieved good results for this example. From left, 15%, 25%, 65%, 85%.

7. Mask dilation iterations increases the amount of area to be removed with the mask by one pixel per additional iteration. This can be used to remove blurry or halo edges left behind from an out of focus masked edge.



3 Here the section image on the left has been processed with a mask dilation value of "5", and the mask edges have been completely removed. The image on the right was processed with a value of "1", and you can still see some green at the mask edge.

8. Click on the "Process Out Chromakey" button to start the processing of the files.

**Processing with these tools did take some trial and error in order to get the mask removed well. Also checking all images for areas within the aperture gap that are compromised by the mask erosion is a good habit. Otherwise the composite's quality may be degraded by black spots on the subject area of the section images damaging the overall composite image.*

Compositing the section images in photoshop

1. Load no more than the first fifty section images into Photoshop. Section images are added in sets of less than fifty to avoid crashing Photoshop's alpha channel stack. Remaining images will be processed in subsequent batches.
2. Make a new master .psd file with the same dimensions as the section images. This new file should come at the end of the list of files currently loaded in Photoshop.
3. Create a new layer at the bottom of the layer stack in the master composite file; fill it with black.

4. Set foreground fill color to white.



5. In order to start processing the files, switch to the last section image to load into the file list. It should be the second to last image in the list, directly next to the master .psd file that was just created.

6. Run the “imagemap to alpha fill” action macro on each loaded section image. You will notice that the action closes the processed section image once it has finished with it, removing it from the list of remaining files.

7. Once all the section images have been processed into the master file you are left with only the master open in your file list, switch over to the channels pallet and select and delete the alpha channels created by the action. This will not change the way the image looks as the alpha channels were used to create layers with transparency information in them. These layers still remain after the alpha channels are removed. Delete all alpha channels in the master composite after every batch of files are processed into layers, otherwise Photoshop will fail when creating new alpha channels.

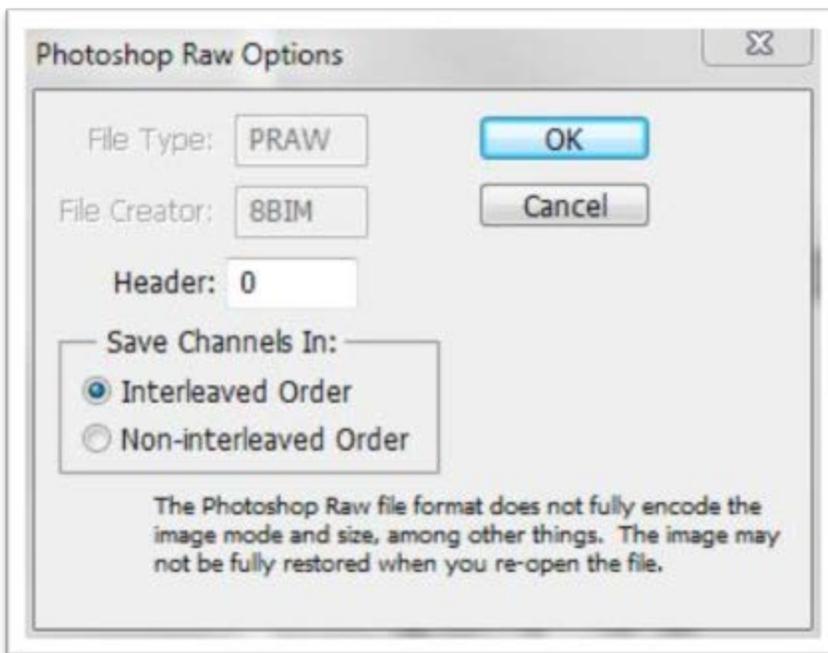
8. Save the master .psd file. Temporarily close the master .psd file.

9. Open the next batch of 50 section images. Now reopen the master .psd file so that it is once again at the end of the list of open files. Switch to the last section image of the batch just opened and repeat running the “imagemap to alpha fill” Action on each loaded section image.

10. Continue this process until all batches of section images have been incorporated into the master .psd.

11. Now you are working in the master .psd file exclusively.

12. If you did not process the masking out of the images with the chromakey processing method you must hide all layers except the black bottom layer and one of the section layers and go layer by layer deleting any visible aperture mask, leaving only what was visible through the gap.
13. Make all layers visible and select all section layers. You should now see a composite of all the values from every section image layered on top of one another.
14. Switch the image color mode to 16 bits per channel.
15. With all section layers selected adjust the opacity to calibrate the values across the full range of grayscale. For a three hundred layer image composite a transparency value between 5 percent and 20 percent allowed for detail in the white areas and dark areas. However this adjustment process requires some attention and additional changes to brightness contrast and exposure values may be necessary, via an adjustment layer.
16. Once the image is adjusted and the calibration is done, flatten the image down so only the "background" layer remains.
17. Convert the image back to 8 bits per channel.
18. Save as a Photoshop Raw file (.raw) with zero size header, and with the channel values in interleaved order.



4 Photoshop raw file save settings dialogue box.

19. Open the texture map image you plan to use for the color values in the three dimensional rendering. Save as Photoshop Raw file with zero size header, and with the channel values in interleaved order.



The image above shows three different exposure levels from the same composite master file, each image also displays an accompanying histogram of brightness values. The example on the left is underexposed and its histogram shows just one mass of values located across the dark end of the spectrum. The image on the right is over exposed and has a range of values that fall out of gamut on the top end of the spectrum; this will cause a subsequent flattening of the geometry output. The image in the middle is most evenly exposed with a histogram showing greyscale values distributed across the majority of the spectrum.

Processing 3d outputs and visualizations with Daxelject

The Daxelject software can produce output files of several different types however this section will focus on the .X3D output option.

.x3d pointcloud rendering

1. Start the Daxelject software and begin under the heading "File".
2. Click the "Select raw file" button and browse to the texture map .raw file for the item you want to make a rendering of and select "open". You will see the name of the file appear in the field below the button once it has been selected.
3. Click the "Use height map" button and browse to the composite map .raw file for the item you want to make a rendering of and select "open". You will see the name of the file appear in the field below the button once it has been selected.
4. Click the "initiate save file" button and create a new file name in the location where you want the file saved. In the case of creating a new .x3d file, please make sure to correctly name the file with the ".x3d" extension on the end.
5. Enter the x and y pixel dimensions for the .raw images being processed in to the appropriate fields marked for length and height. The x and y values should be exactly the same for both the texture map and the displacement map.
6. The "Z space divisor" field has a default value of "1" and should be set to "1" for the first test rendering of a new .x3d file. The value in the "Z space divisor" field is used to compress the height values taken from the displacement map, so a value of "1" equals no compression where as a value of "3" squishes all height values down to a third of the size they are in the displacement map. This can be helpful to adjust if there is a lot of noise or choppiness in the surfaces being produced. Compressing the difference in height values does distort the geometry by flattening it; however, this can make the overall surface produced look clearer
7. Click the "Render to X3D" button and the file will be produced shortly.

Second Method

Setting up the camera Canon Power-shot A810

Setting up the camera and the subject is important to getting a good scan. Some things to keep in mind:

The closer to the lens you can get the subject, the shallower you can make the depth of field, and this is what produces the thin film of focus that this process relies on

Illuminate the subject from 180 degree opposing angles to get the best chance of drawing surface texture into contrast

Place the closest part of the subject about 3-4 inches away from the lens and remember you have about 8-10 inches of working distance past the 3-4 inch beginning position

You can set the camera settings to a desired resolution before you begin the automation process; I find the 640x480 resolution to be fast and provide a decent amount of data

1. Place a memory card with an appropriate version of the CHDK environment installed on it, and a copy of the LUA script DXL_CAP.LUA located in the root directory, into the camera while the camera is turned off and the write lock is in the "locked" position. (The A810 uses 1.00e version 1.3.0)
2. Turn the camera on with the "ON/OFF" button, you will see the CHDK splash screen
3. Press the "playback" button marked with the rectangle with a triangle in it. This will switch you over into the "ALT" CHDK mode so you can run LUA scripts
4. Press the "Menu" button
5. Navigate to the "Script" option, press "FUNC. SET"
6. Navigate to the "Load script from File" option, press "FUNC. SET"
7. Select the DXL_CAP.LUA file and press "FUNC. SET"
8. Navigate back to the main menu screen by pressing the "playback" button twice

Running the script dxl_cap.lua

1. Press the shutter button to run the script
2. The script will tell you to remove your hands from the camera and it will give you an update as to the time it still has remaining until it is finished taking all of the captures
3. You will hear the script triggering the shutter about every 2-3 seconds
4. Do not touch the camera while it is making the captures as this will result in the whole set of images being unusable
5. Wait until it is finished
6. Once the script is done turn off the camera
7. Remove the memory card and switch the write lock back to "unlock"

Processing the depth-field captures into a displacement map

1. Move the set of images off of the memory card and onto your computer
2. Place the set of images you want to process into a displacement map into the Daxelject folder named seq_in
3. Launch the Daxelject software
4. Under the "File" heading on the left hand side of the interface click the initiate save file button and choose a file location where you want to save the displacement map
5. Choose a file name and add the extension .raw
6. Under the "depth field processing" heading click the "select depth field files location" button and browse to the "seq_in" folder in the Daxelject program folder.

7. Click on the “select save location for processed files” button and browse to the “seq_out” folder
8. Type a value from 1 – 100 in the “confidence threshold” field; this will adjust the sensitivity of what the script considers a an accurate assessment
9. Click the “process height map from depth field images” button
10. Once the displacement map is completed, close and reopen the software

Transforming the displacement map into a closed mesh object

In order to begin this part of the process you will need to select one of the depth field images you made and convert it into a headerless photoshop raw file. This process can also be done with Imagemagick or another software if desired. Select an image from the depth field stream that is in the middle of the focus range, for example if you have a depth field stack of 100 images use a good looking image around the 50th one. Open this file and save as Photoshop raw.

1. Under the “file” heading in the Daxelject software click the “select raw file” button and browse to the .raw image you just saved from the depth field stream.
2. Click on the “use height map” button and browse to the displacement map that you just created.
3. Click on the “initiate save file” button and decide on what type of 3d output file you are intending to make, either the .STL or the .WRL and name you file accordingly
4. Click on either the “render to STL” or “render to WRL closed mesh” button, based on what you decided to output to.
5. Wait until the program is finished exporting the mesh file

Viewing the created mesh object

I have been using the open source MeshLab software to look at my 3D objects because it is a good package and handles the types of files that the Daxelject software and process creates; however, there are many other softwares that can view and manipulate these types of files.

1. Open the MeshLab software and select “file”
2. Then “import mesh”
3. Browse to your newly rendered 3d object and load it into the display
4. Choose the “render” dropdown and then the “lighting” option and switch it to off
5. This will disable the dynamic shading of the mesh in the display so that the true colors from the texture-map will be displayed. This will make the image much more readable.