Digital Volume Correlation User Manual

Introduction

The Digital Volume Correlation package is composed of six MATLAB files. The functions analyze a series of images of a material taken via Laser Scanning Confocal Microscopy and track the displacement of the material at atomic-scale resolution in three dimensions. Below is a list of the .m files and their function in this process:

automate_image3.m – The main function of the program that orchestrates the correlation. Assembles volumes, than cycles through all volumes, breaking them down into subvolumes and correlating them with the base by calling cpcorr3

cpcorr3.m – Adapted from the private MATLAB cpcorr function, this function takes subvolumes and passes them to normxcorr3 and then findpeak3 to track the displacement. Can be modified for anisotropy and to toggle subvoxel resolution.

filelist_generator3.m – First function called, asks user to input the first image filename and then generates a list of all the pictures' filenames to use for the correlation

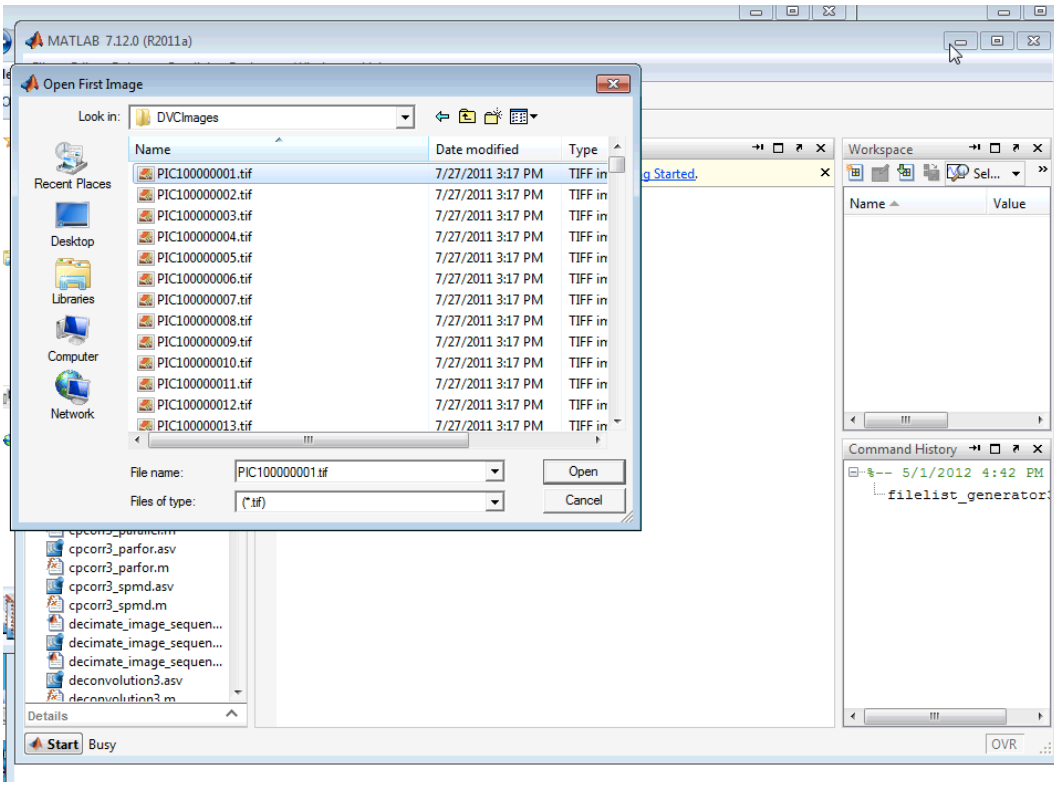
findpeak3.m – This function achieves sub-voxel resolution for the volume correlation though interpolating the space between raster points.

grid_generator3.m – This function is called before beginning the correlation to generate control points. The user can define the region of interest and input resolution values for all 3 dimensions to create the grid

normxcorr3.m – Adapted from the MATLAB function normxcorr2 for three dimensional matrices, this function is called from cpcorr3 and generates the correlation coefficients between the current subvolumes and base subvolumes.

Set up File List

Type filelist_generator3 and press enter. For the first prompt displayed, select automatically. In the main prompt, navigate the computer to the directory containing the images to be correlated, and select the first image.

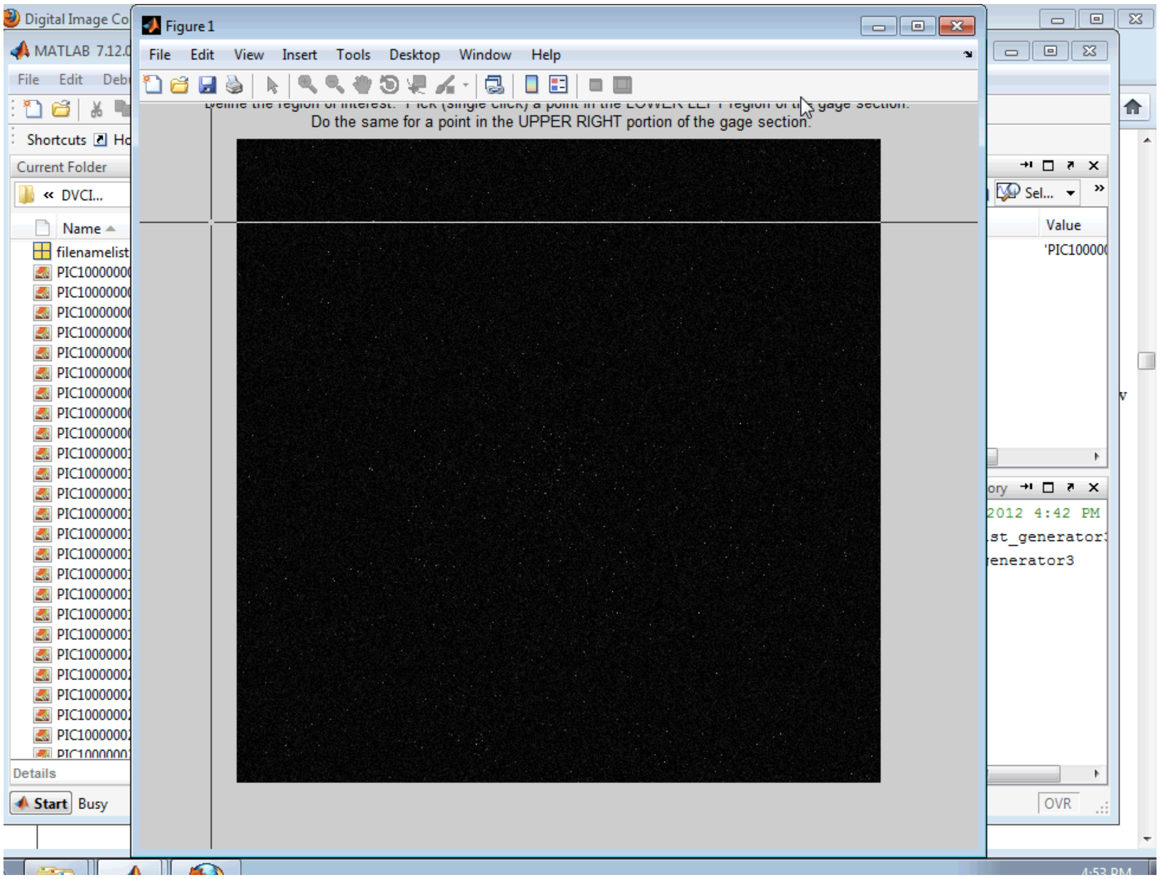


Screenshot: Choosing base image

The next window asks you to choose where to save the file named: “filenamelist.mat” It is best to save this file with this name in the directory where your pictures are located (the default option).

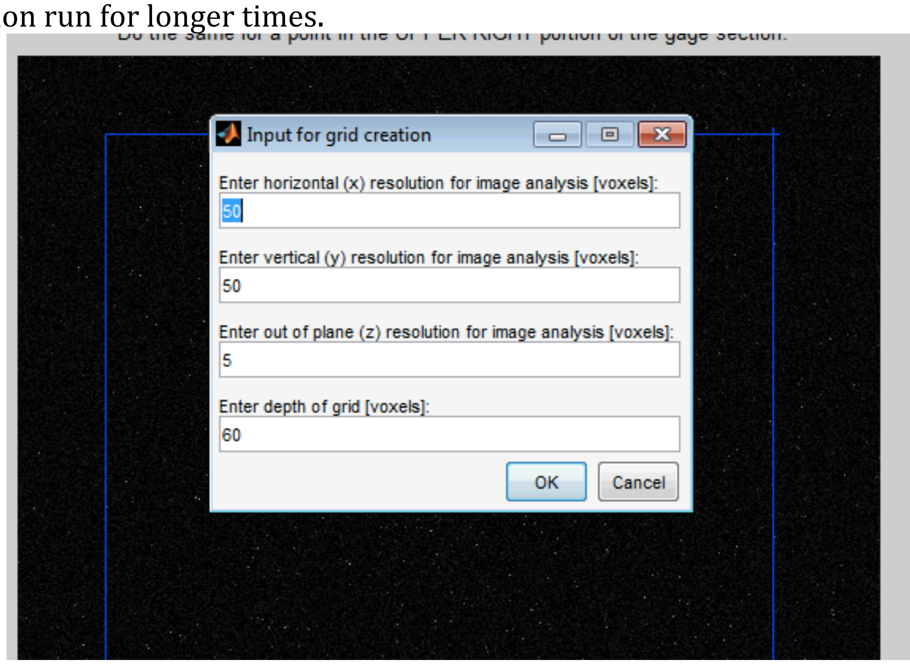
Generate the Grid

Now that the program has a way to go through all the images, it will set up the base grid to track displacements. Type grid_generator3 and press enter. A window will be opened asking you to select an image. Choose the first image (name with 0001.tif). Another prompt will ask what kind of grid you would like, select Rectangular. The current window now is displaying the first image. Define the volume of the grid by clicking a point in the lower left corner and then a point in the upper right corner.



Screenshot: Setting grid dimensions

The next window lets you define the resolution. The higher the resolution, the more finely spaced the grid will be. Inputting large numbers here can make the correlation run for longer times.

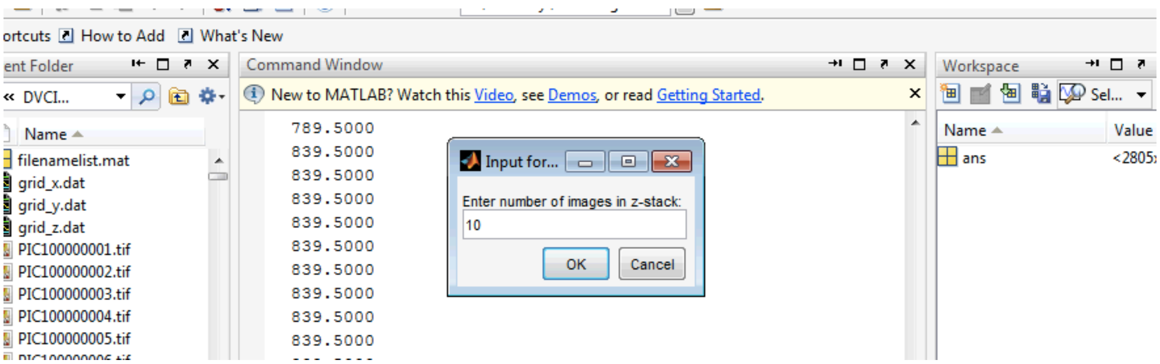


Screenshot: Setting the resolution for each dimension

A sample grid will be displayed on top of the base image, select yes if you find it suitable. Otherwise follow the option to repeat this step. After selecting yes, 3 new files will be put in the directory, grid_x.dat, grid_y.dat, and grid_z.dat.

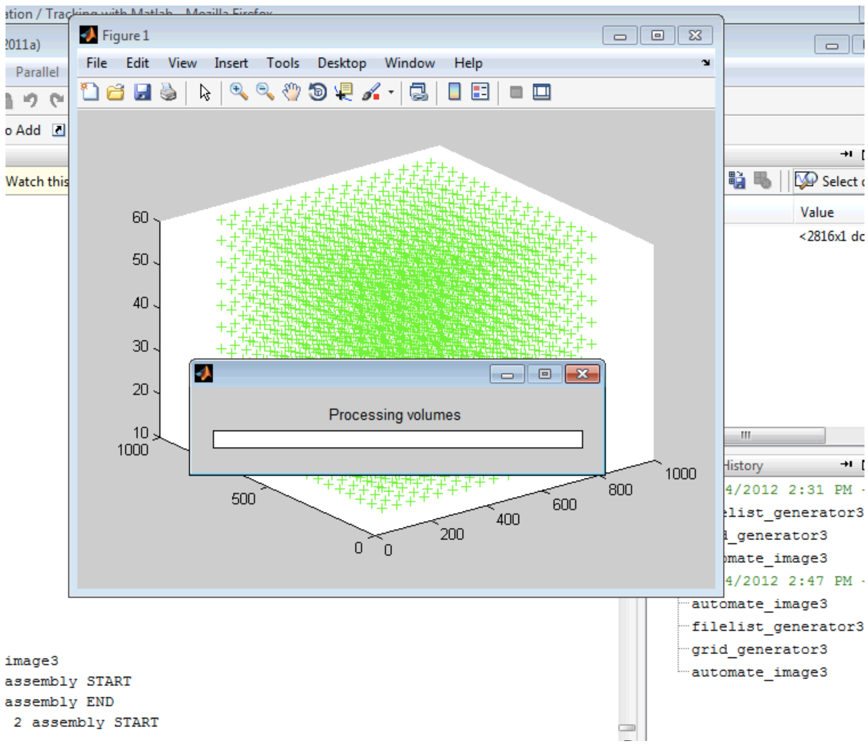
Perform the Correlation

Everything is now ready for the correlation to proceed. Type automate_image3 and press enter. A prompt will ask how many images are in the z-stack, which would equal the amount of pictures taken at each elevation. The program uses this to process the images into a volume.



Screenshot: Defining the number of z-stacks

Next you will be prompted for corrsize. The corrsize defines the amount of pixels in each direction that form a subvolume, so entering a small corrsize can lead to much longer runtimes. Choosing a corrsize of 10 defines a subvolume as 20X20X20 voxels. Entering the corrsize and pressing OK begins the correlation.



Screenshot: Beginning of Calculation

By default, cpcorr3, which is called by automate_image3, assumes the noise in data is the same for all three dimensions. However, this is not always the case and sometimes it is important to correct for anisotropy in the z direction. To correct for this, make the following three modifications to cpcorr3.m before running the program.

1. Comment out line 66 and remove the % symbol at the beginning of line 68 so that block of code appears like below:

```
65      % Offset found by cross correlation
66       %corr_offset = [(xpeak-inputsize(2)-CORRSIZE) (ypeak-inputsize(1)-CORRSIZE) (zpeak-in
67      % Modification 1 of 3 for accommodating anisotropic subvolumes
68 -    corr_offset = [(xpeak-inputsize(2)-CORRSIZE) (ypeak-inputsize(1)-CORRSIZE) (zpeak-inpu
69
```

2. Comment out line 103 and remove the % sign from line 105 so that the block of code appears like below:

```
103  % default_depth = default_width;
104  % Modification 2 of 3 for accommodating anisotropic subvolumes
105  default_depth = default_width/2.5;
```

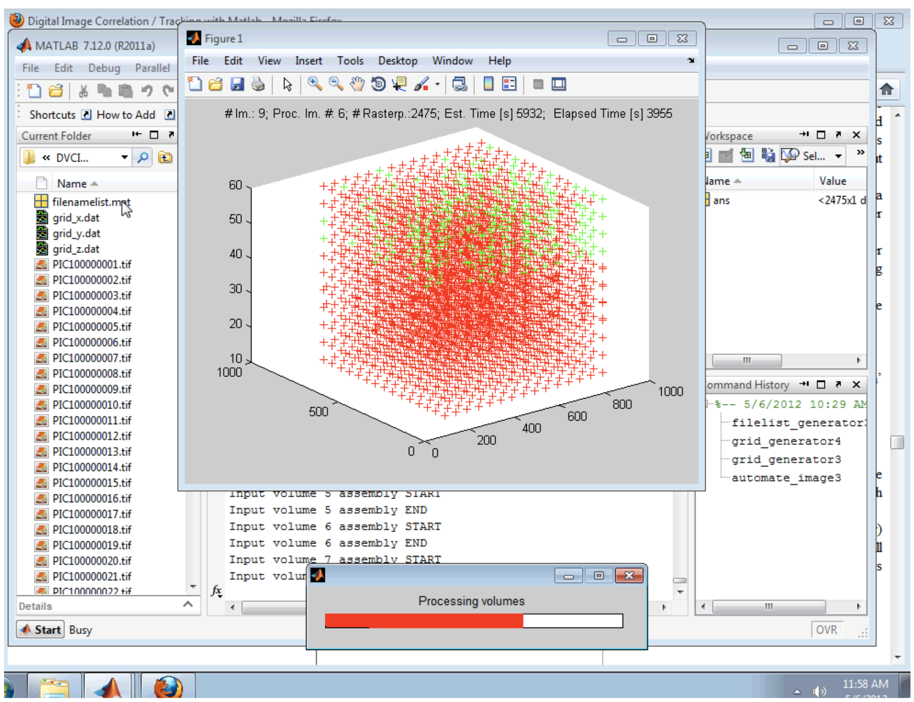
3. Comment out line 109 and remove the % signs from 111 and 112 so that the block of code appears like below:

```
108    % xyz specifies center of rectangle, need upper left front
109    % upleftfront = round(xyz) - halfwidth;
110    % Modification 3 of 3 for accommodating anisotropic subvolumes
111 -  b = ones(size(xyz));
112    upleftfront = round(xyz) - [b(:,1)*halfwidth b(:,2)*halfwidth b(:,3)*round(halfwidth/2.5)]
```

Another default is to always interpolate between raster points to attempt to attain subvoxel resolution. To disable this, set the Boolean variable subpixel to false in line 54 so that the code appears like below:

```
53        % Get subvoxel resolution from cross correlation
54 -      subpixel = false;
55 -      [xpeak, ypeak, zpeak, max_cc] = findpeak3(norm_cross_corr,subpixel);
```

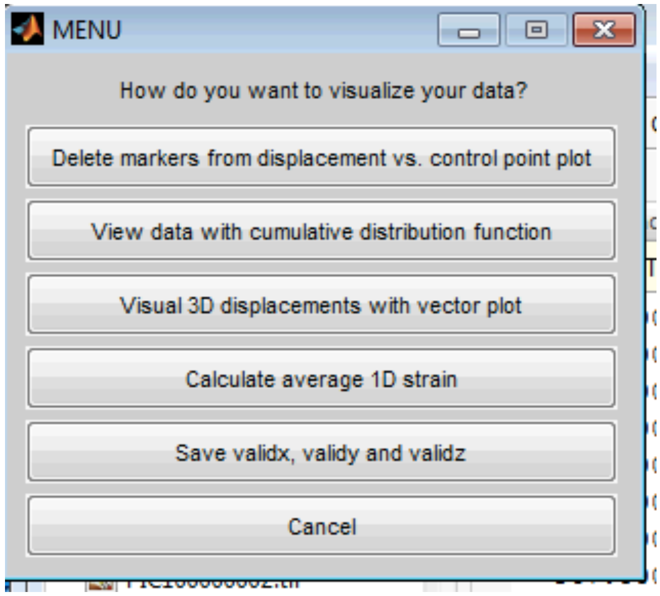
When the correlation is finished running, three new files will appear in the directory: validx.dat, validy.dat, and validz.dat. These files store how the coordinates of the raster points change with time, and thus are important for analyzing displacement. Note that on a typical computer, processing 3060 images with resolution of [50 50 60] and corrsize 20 takes about two hours. If all is running smoothly, the screen should appear like below while automate_image3 is running.



Screenshot: Performing the correlation

Visualize the Data

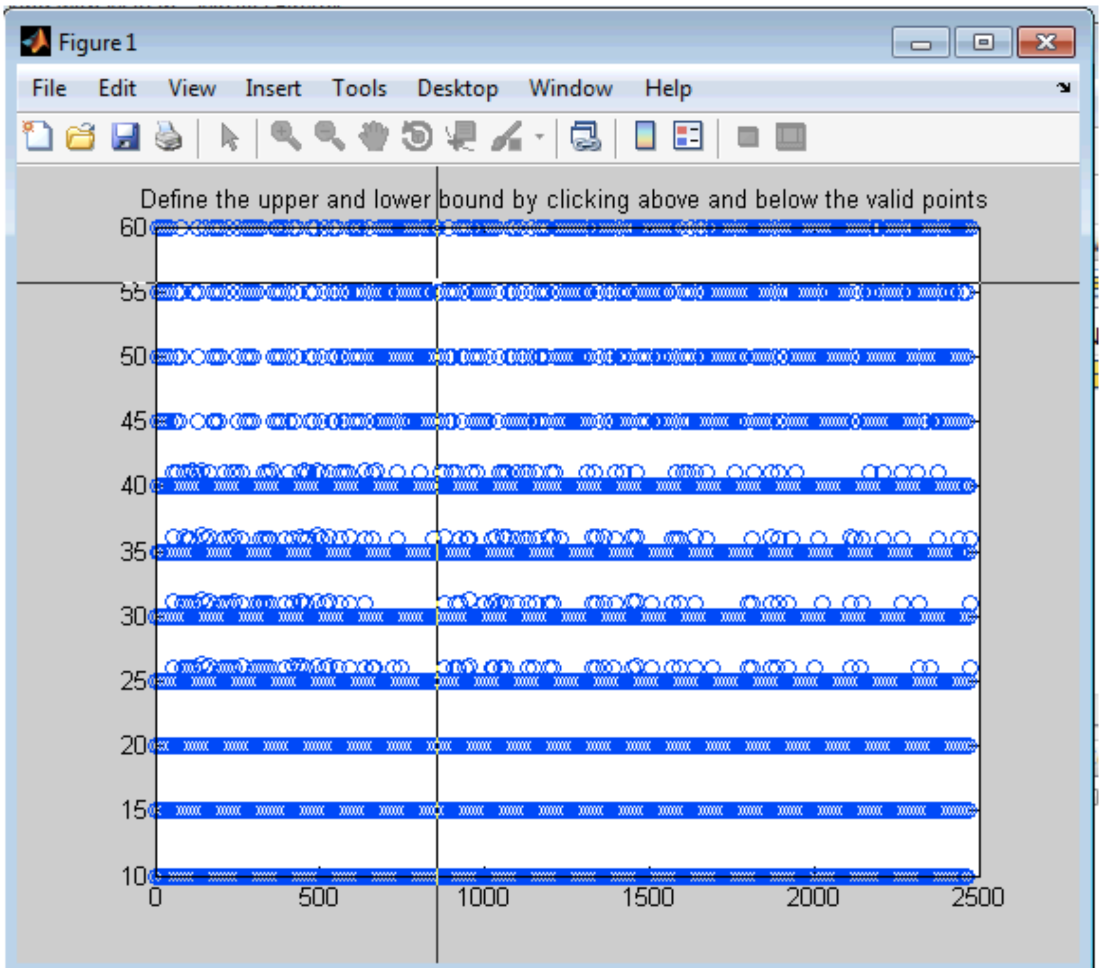
Type in displacement3 and press enter. The first prompt will ask you to select validx.dat, then validy.dat, then validz.dat. After doing this, a menu will appear like below:



Screenshot: Visualization Menu

The possible options on the menu are: Delete markers from displacement vs. control point plot, View data with cumulative distribution function, Visual 3D displacements with vector plot, Calculate average 1D strain, and Save validx, validy, and validz. Starting on the next page are instructions on using each feature:

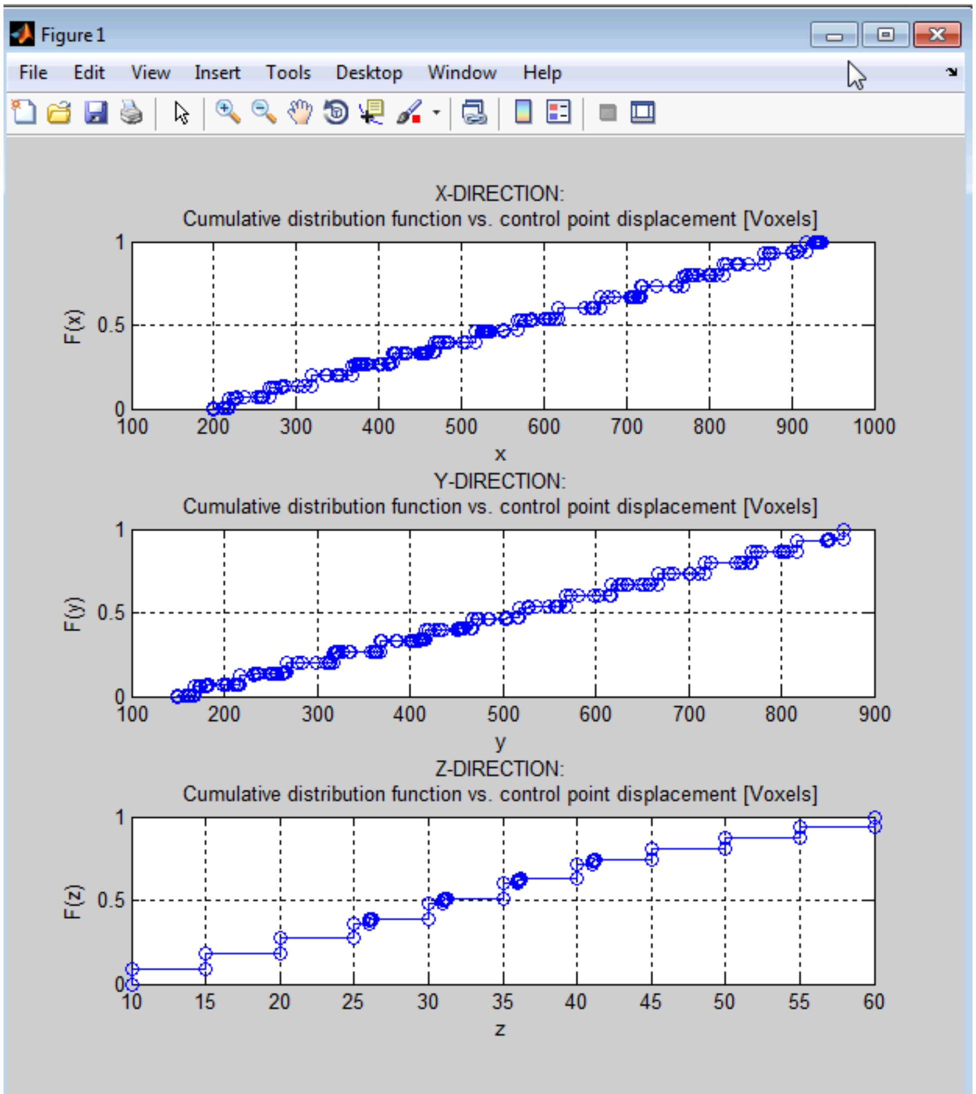
- Delete markers from displacement vs. control point plot: After selecting this option, the next menu will have three buttons for deleting from validx, deleting from validy, and deleting from validz. After selecting a coordinate, a new figure will appear with a displacement vs control point plot and all the markers. Click near a marker to define an upper and lower bound for what you would like deleted.



Screenshot: Deleting points from validz

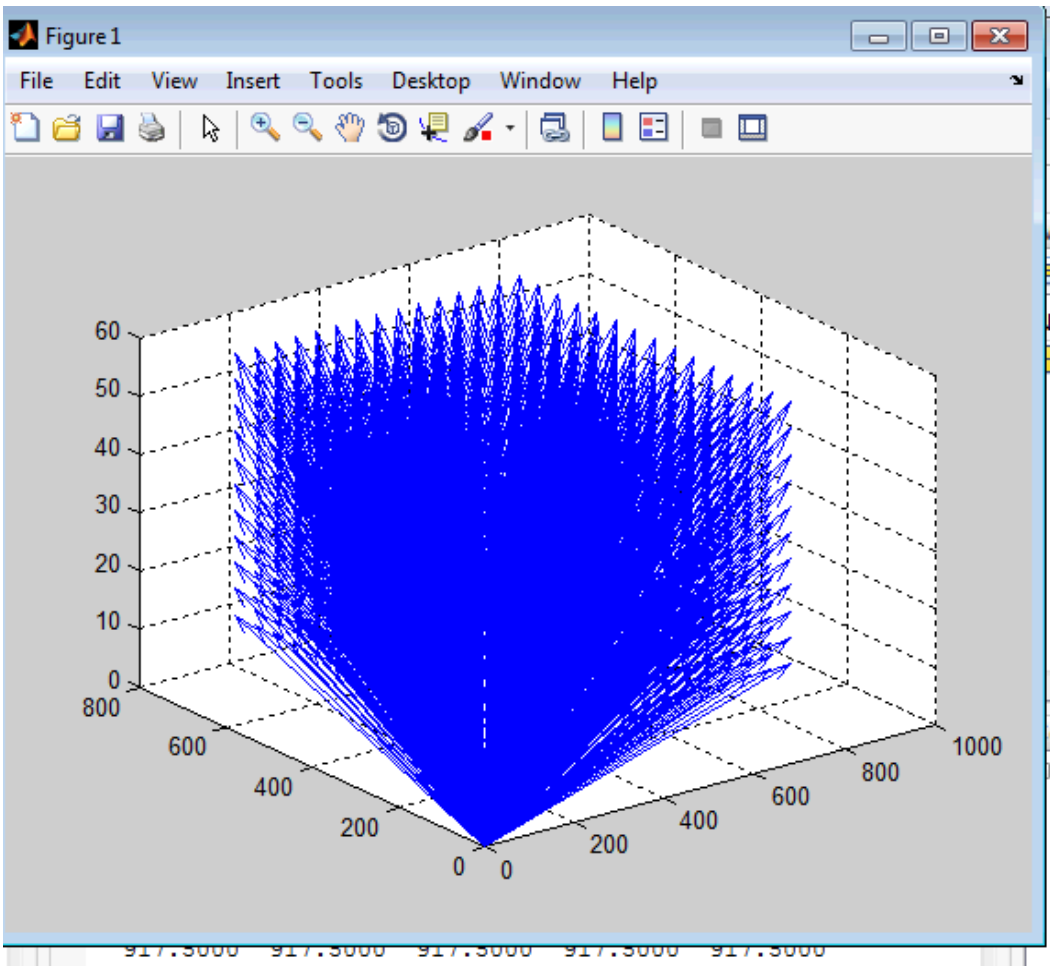
After deleting the point, a menu will ask if the result looks as expected. You may either accept the changes and move on, delete more points, try the whole process again, or cancel.

- View data with cumulative distribution function: Selecting this option will generate a new figure like the one below:



Screenshot: Cumulative Distribution Function Analysis

- Visual 3D Displacements with Vector Plot: Selecting this option will generate a new figure like the one below:



Screenshot: 3D Vector Field Analysis

- Calculate Average 1D Strain: Selecting this option gives a new menu, with options to calculate strain along the x, y, or z direction. After selecting a direction, a new prompt asks if you would like to create a video. If you select yes, a new folder named videostrain will be created in the directory for this purpose.
- Save Validx, Validy, Validz. This option takes you to a series of three prompts that allow you to save the respective files on the computer.

Advanced Options

Above is a typical basic run through of the DVC program, applicable to many situations. There have been special functions written to run for larger displacements and to optimize processing speed. Using large_dipsl3 allows a user to define a reduction factor, and then calls grid_generator3 and automate_image3 on its own.

The cpcorr3 function has been rewritten to perform better using parallel computing on computers with multiple processors. The cpcorr3_parallel and cpcorr3_spmd functions can be called. This functionality exits for automate_image3 as well, by using the files automate_image3_multicore and automate_image3_parallel.