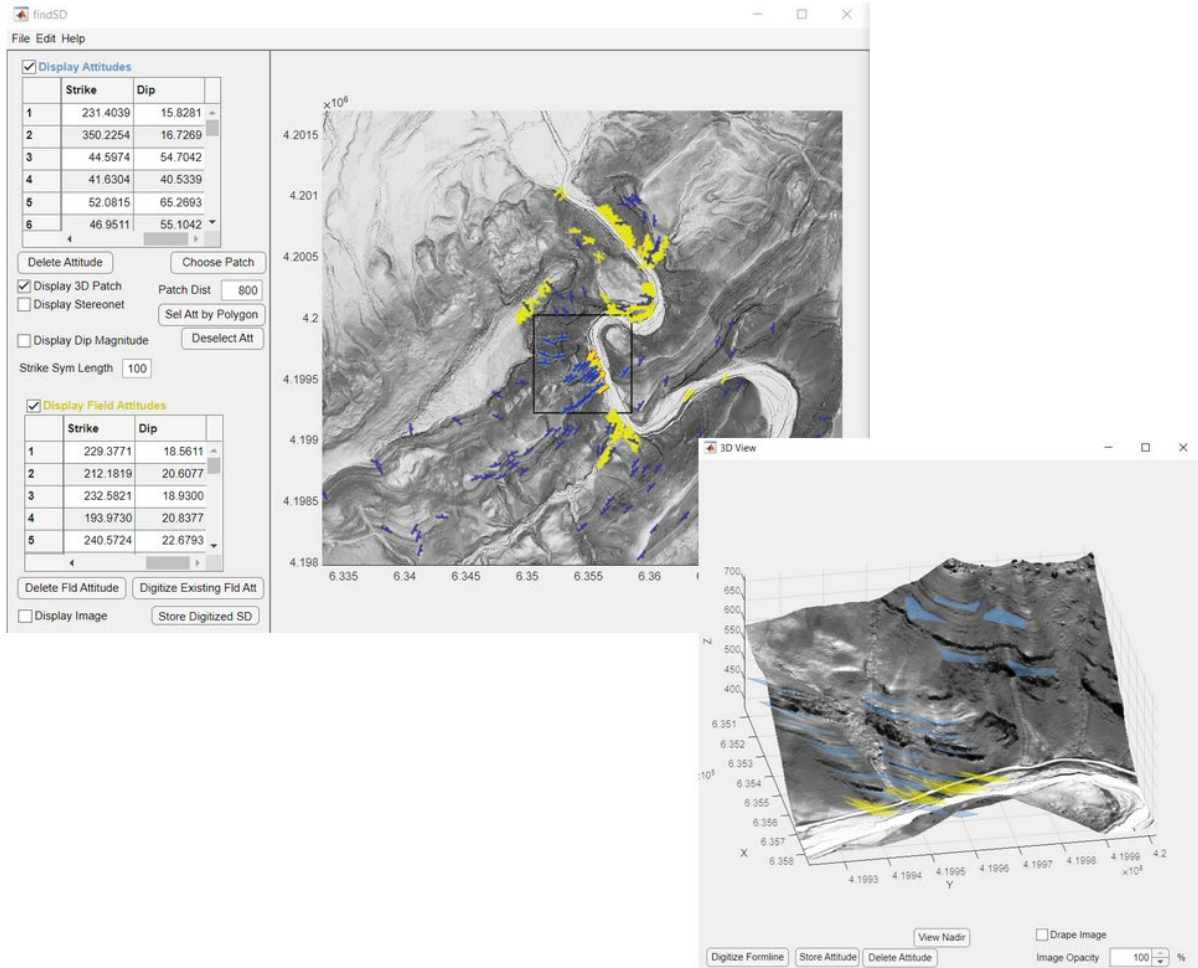


findSD Manual, v 1.11
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November, 2023

findSD - A structural geology tool for planar attitude (strike and dip) determination and visualization.

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Installation

The program findSD is written in MATLAB. It should run on Windows 10 and 11, 64bit. A version for macOS is coming soon. The program only comes as a compiled stand-alone application. Source code is not being provided. Run the “findSD_installer.exe” This will install a compiled version that does not require that you have a license for MATLAB. During installation the MATLAB runtime libraries will be downloaded and installed to allow for full use of findSD. If you do have MATLAB R2023a, then it should just install the executable.

Background

findSD is a structural geology tool for planar attitude (strike and dip) determination and visualization. The details of the program will be explained in Connors (*in prep*). Once published, I ask that you cite the manuscript when presenting the results of findSD determinations. Until that time, please cite Connors et al. (2023). A brief description of the theory is given here. If you find a bug, please email connorsc@wlu.edu. If you have a desire for new features, likewise feel free to email, and at some point, they may be incorporated, but the program is not intended to be a feature-rich, commercial package. findSD is a simple program that I use in my research and teaching, and I am sharing it with others with the idea that some structural geologists may find it useful. It is provided “as is,” without any warranty, and no implied warranties. See the notice at the end of this manual or the About Menu in findSD for more details.

findSD allows for determination of planar orientations from high-resolution digital elevation models (DEMs) such as those from the USGS 3DEP DEMs derived from lidar. A DEM is first visualized as a nadir hillshade which is draped onto a 3D surface. “Formlines” are then digitized along the surface. These formlines represent the geologist’s interpretation of the bedding (or perhaps other planar feature) in the visualized 3D surface. A best-fitting plane is computed from the points. Thus, the actual points are an interpretation, with the resulting plane’s associated strike and dip located at the centroid of these points. The mathematics of the planar determination will not be addressed in this manual, but the key interpretation to keep in mind is that the points need to approximate a plane. If the points are co-linear (or close to it) then the solution of the best-fitting plane is non-unique and the calculated strike and dip will not be correct. Make sure to have the points look more like they lie within a strongly oblate spheroid (pancake), rather than a prolate spheroid (sausage). Also, make sure to inspect the surface that represents the plane and confirm that you as the geologist believe it represents the bedding plane that you see in the 3D surface. The plane can be very sensitive to the digitized points. It generally is best to spin the model around to determine this based on different orientations. If you find that the plane does not seem to be correct, re-digitize the formline. This is the most important thing to keep in mind to get high-quality measurements of bedding attitudes.

findSD can also be used to extract strike and dip measurements from existing geologic maps. This is done by digitizing the strike symbol with two end points (using the right-hand rule), and then manually entering the dip magnitude. The XY location of the attitude is the mean of the two points, and Z (elevation) is extracted from the DEM at this location. The faithful extraction of this strike is dependent on the correct digitization of the location of the two end points and entered dip magnitude.

Assumptions

In either attitude determination discussed above the assumption is that the imagery and DEM are in a Universal Transverse Mercator (UTM) projection and grid system with the appropriate UTM zone for the area of interest. The mathematical determinations are only valid if this correct UTM zone is used. Vertical and horizontal units should be the same, i. e. meters. All imagery must be exactly the same size and resolution and in the geotiff format. The higher the resolution of the dem, the better the determination will be.

Other assumptions for extracting strike and dip from formlines include the following ideas.

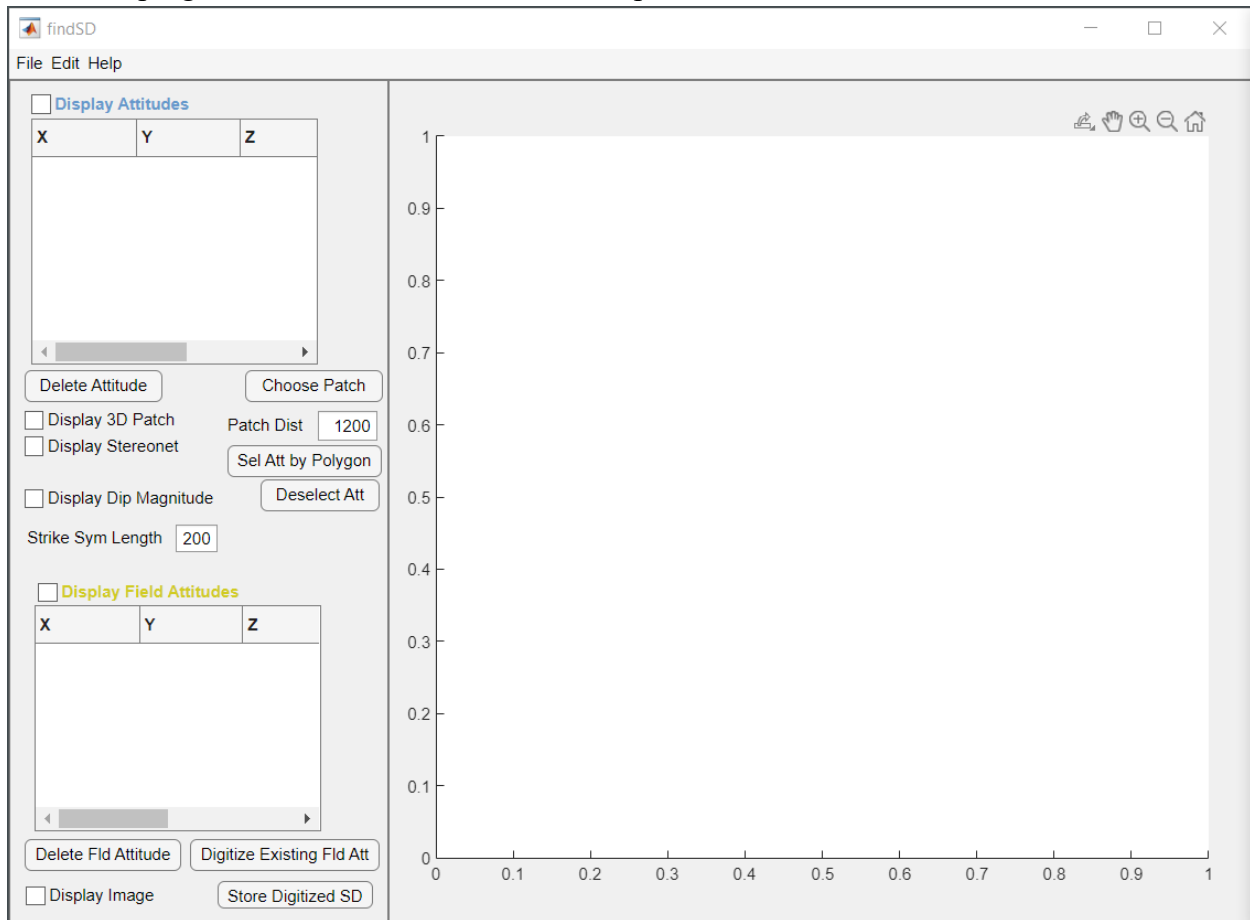
1. The resolution of the DEM and the differential weathering is adequate to distinguish bedding. That is, one can see bedding in the hillshade or draped image.
2. One can define a formline (XYZ points) that approximately lie in a plane.
3. Points on the surface are closely approximating a rock outcrop if it were exposed.
4. Colluvium, alluvium, and manmade features are not incorporated in the formline, or at least minimized.
5. The bedding is not changing orientation at higher frequency than the chosen region to define plane.

Limitations include:

1. Areas with flat topography don't work well and are highly sensitive to noise on the surface.
2. Cliffs in DEM don't work well because the formline is poorly defined in three dimensions.
3. If there is no differential weathering, it may not be possible to see the bedding in the nadir hillshade.

Getting Started

When the program is invoked a window comes up as shown below.



“Attitudes” refer to those determined by fitted planes to points digitized on 3D surfaces. These are blue in the program.

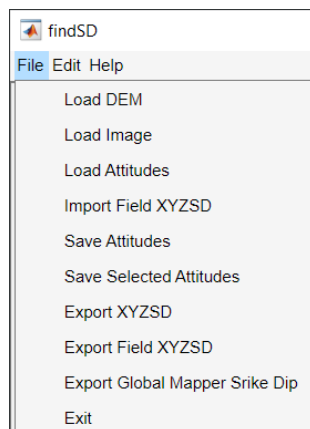
“Field Attitudes” refer to those that the structural geologist has measured in the field and imported into findSD, or those extracted from a geologic map from within findSD. These are yellow in the program.

Description of Menus

The **File Menu** allows for loading digital elevation models, satellite imagery, and images of geologic maps in geotiff format. These have to be in a UTM projection, with the same UTM zone, be the same area/size, and be the same resolution.

With the **Save Attitudes** and **Load Attitudes Menus** you can work with data in the program during multiple sessions. These are MATLAB structures with 2 matrices and a cell array and can be interrogated within MATLAB, but it is not necessary to know this structure in order to use findSD, or to get your measurements out of the program through exporting. Thus, this data structure will not be explained further here, but should be obvious for anyone familiar with MATLAB. If there are existing Attitudes or Field Attitudes the loaded attitudes can be appended to the existing on loading.

The other choices in the **File Menu** are for importing and exporting text files for use in other programs like geographic information systems or structural modeling programs. “XYZSD” refers to comma-delimited text files of values with five columns: UTM Easting (X), UTM Northing (Y), elevation in meters (Z), right-hand rule strike in degrees (S), and dip magnitude in degrees (D). If you choose **Import Field XYZSD Menu** the format of this text file should be the same. If there are existing Field Attitudes the imported measurements can be appended to the existing on importing.



The **Edit Menu** has menu choices that are fully replicated by the buttons and checkboxes in the main window. So, it is not really necessary to use these menu choices, but they are provided for those who prefer to use menus.

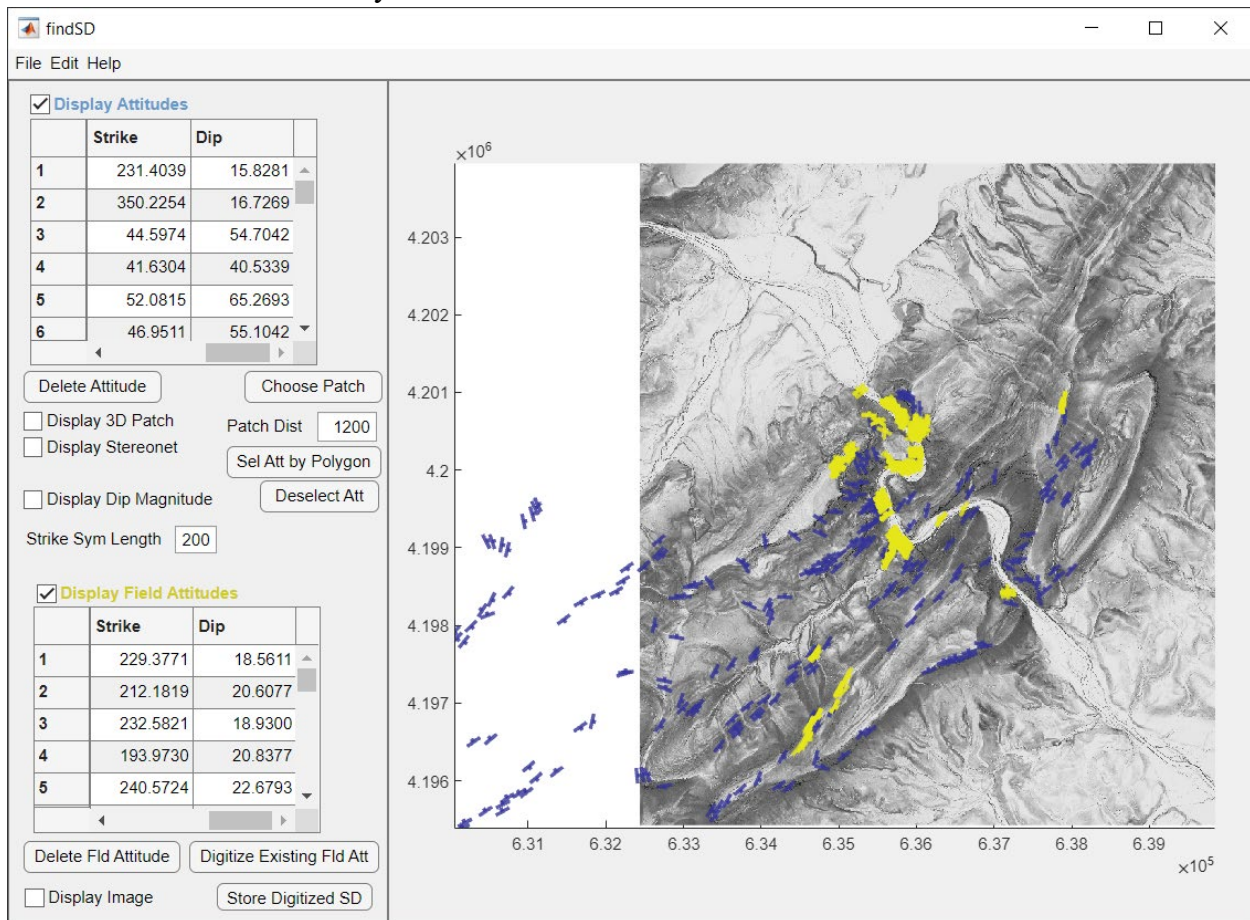
The **Help Menu** invokes this manual, and basic information about the program.

Workflow, Buttons and Checkboxes

Loading Data

The general workflow is to load a DEM and maybe an image into the main window by making choices in the **File Menu**. If you have previous Attitudes or Field Attitudes you can load these too through the **File Menu**. Once that is done the main window will be populated like that shown below. On the left the **Attitudes Table** and **Field Attitudes Table** show your existing attitudes. When new Attitudes or Field Attitudes are digitized, they are added to the respective tables. Also, on the left are buttons, checkboxes, and edit boxes to control the map display, and interact with data, such as invoking a 3D view of an area called a patch.

Although attitudes have to be extracted on a DEM, it is possible to have previous attitudes extend beyond the existing DEM. Thus, allowing for more regional compilation of data, with small local DEMs used at any one time.



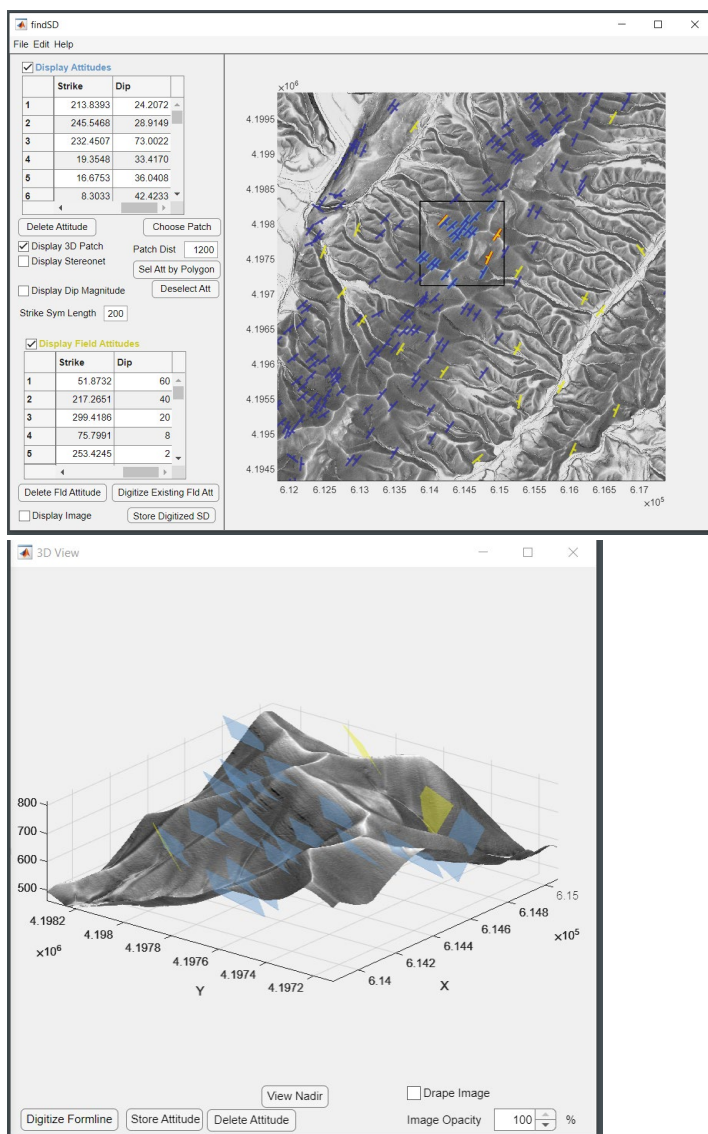
Visualizing the DEM and Attitudes

Click the **Choose Patch Button** and then click the area of interest in the map. If a DEM is loaded this will bring up a window with a 3D view of the surface. The square on the map in the main window indicates the area of the surface patch that is shown. The **Patch Size** can be

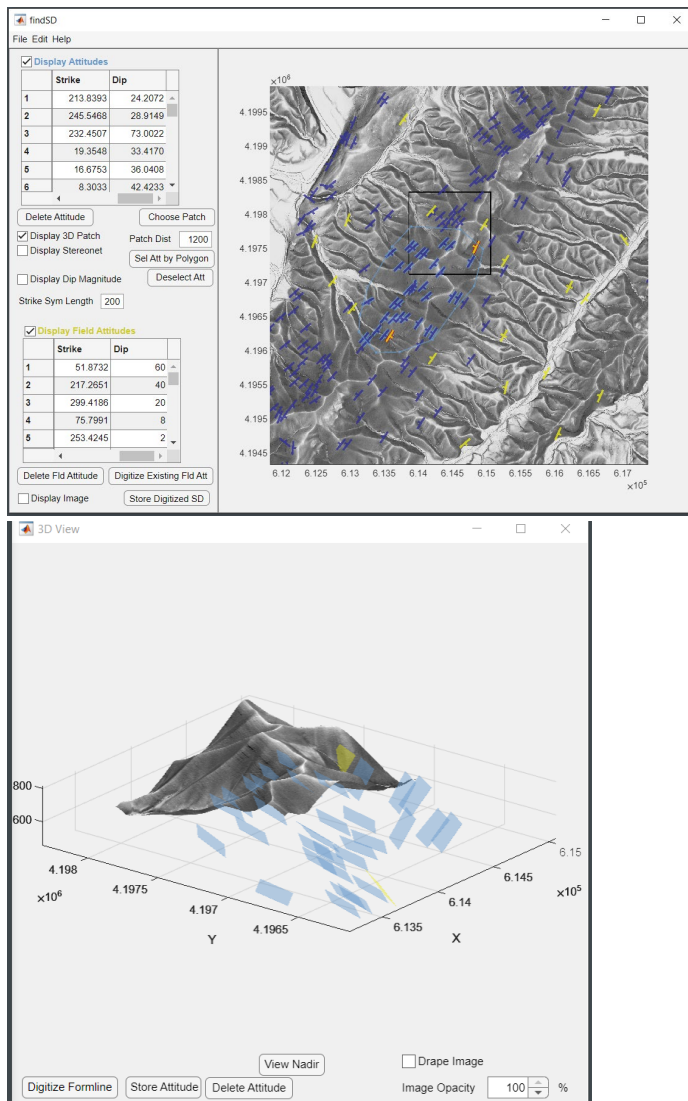
changed, and will update the regions of interest. With just a DEM loaded a draped, shaded-relief will be shown on the 3D surface.

If an orthoimage from a satellite is loaded then this can be draped on the surface. This might be useful in areas where the DEM is low resolution and the orthoimage might provide additional detail. Note, a DEM still has to be loaded to provide 3D information. A word of caution here: many orthoimages have artifacts or distortions that should be ignored when trying to follow a bed along a 3D surface. It is best to toggle back and forth between displaying and hiding the orthoimage to really confirm the bedding determination.

When a patch is selected the Attitudes and Field Attitudes that are within the patch will also be selected. These selected attitudes are shown in the 3D view and highlighted in the map view.



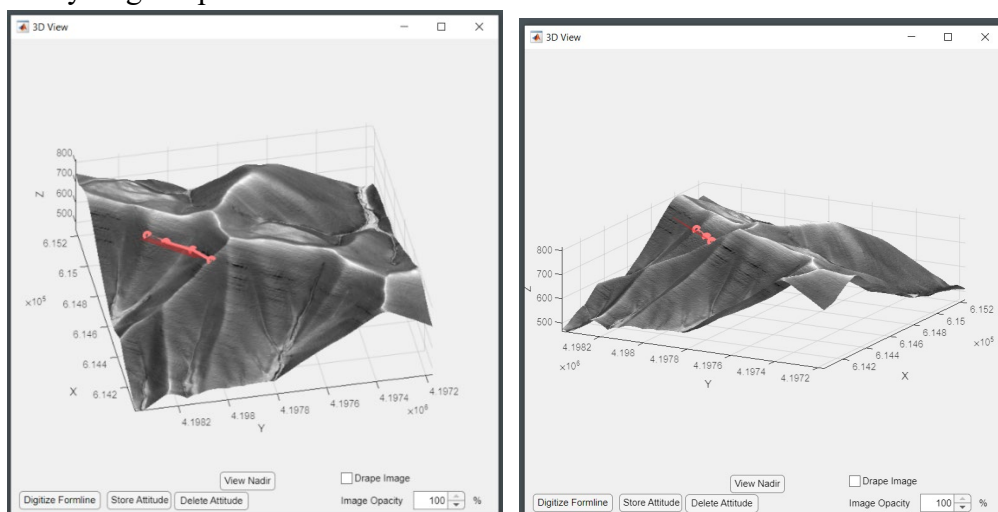
Instead of the Attitudes and Field Attitudes being selected within a patch, one can select attitudes within a digitized polygon. This is done by clicking the **Sel Att by Polygon Button** and then using the left mouse button to click points around the desired attitudes, terminating with a right mouse button click.



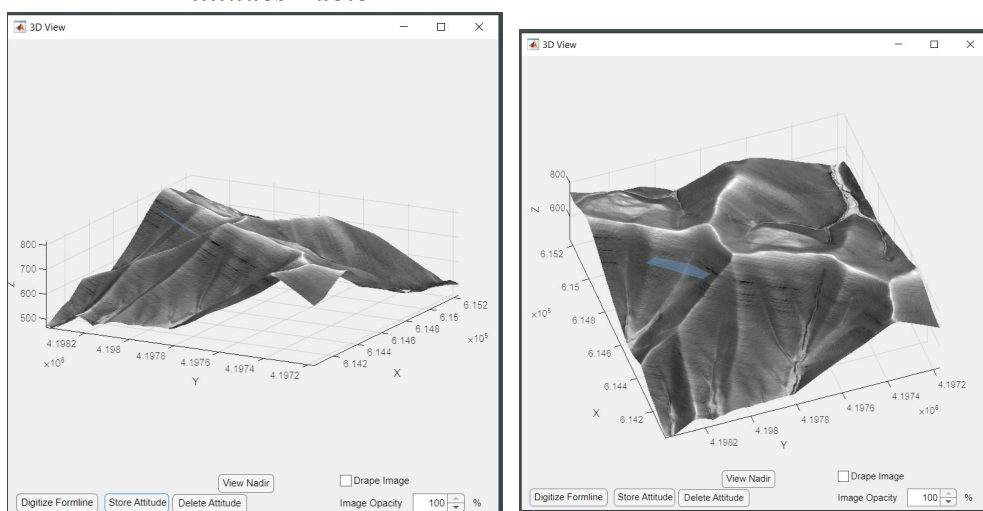
You can delete an Attitude in the map view by clicking the **Delete Attitude Button** and then clicking near, but not on an Attitude in the map. A similar procedure can be done for the 3D view.

Extracting Attitudes from DEMs

The digitization of a formline on a 3D surface is done by clicking the **Digitize Formline Button** in the 3D View window, and then clicking on the 3D surface with the left mouse button all points you want, and terminating it with a click with the right mouse button. The best fitting plane is shown in red. You should spin it around to verify that the plane is representative of the bedding you see in the 3D surface. Looking down the strike, such as the right image below, is always a good practice.



If you like that plane and want to keep it in your Attitudes, then click the **Store Attitude Button**. The plane will turn blue to indicate it is stored, and the XYZ location and strike and dip will be added to the **Attitudes Table**.



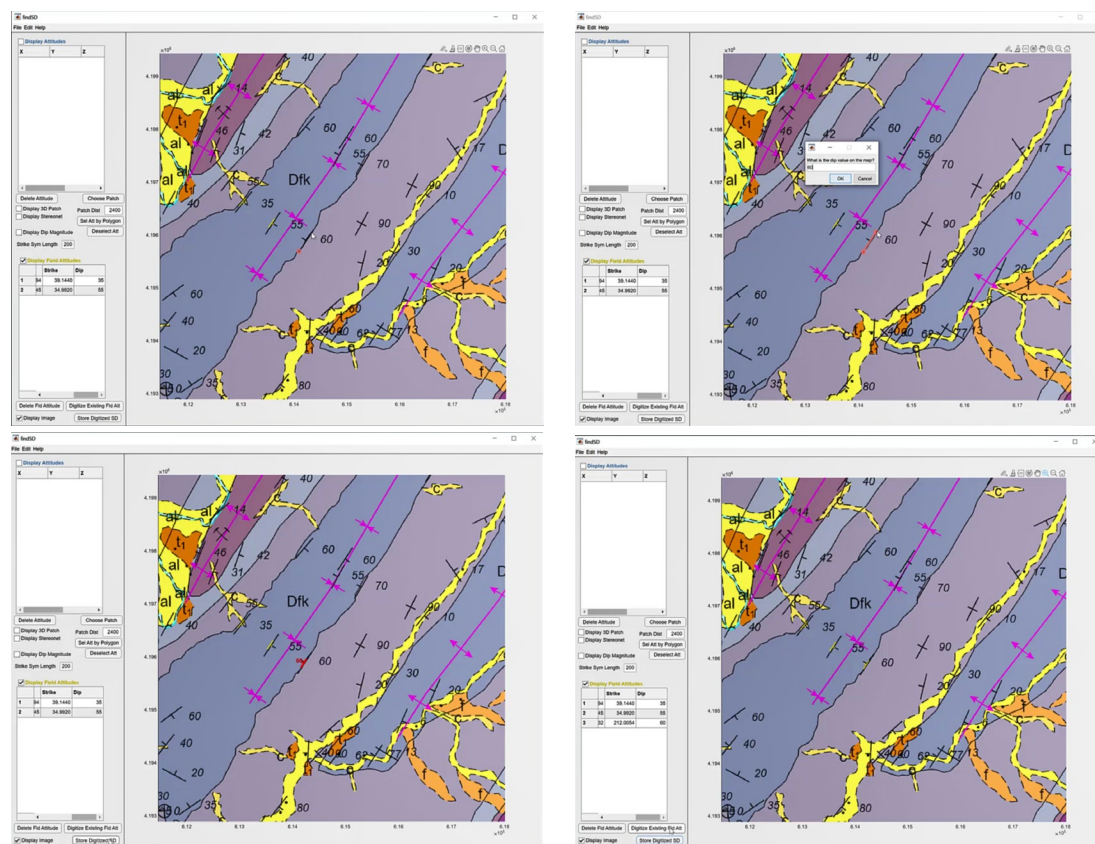
Note, these are only stored in this session of findSD. Exporting or saving from the **File Menu** must be done to record measurements to disk. Saving will allow you want to come back to this project with findSD, including the saved formlines. Exporting will simply save the XYZ position and strike and dip.

To evaluate an existing Attitude, click it in the Attitudes Table. The patch will be centered around it, and a circle selection of Attitudes and Field Attitudes will be selected.

For any selected attitudes one can see a stereonet representation of these by clicking the **Display Stereonet Checkbox**. Any selected attitudes can be exported from the **File Menu**.

Extracting Attitudes from Existing Geologic Maps

Make sure a geologic map and a DEM have already been loaded, and zoom into the area where you can see a strike and dip symbol on an existing geologic map. Click the **Digitize Existing Fld Att Button**, and then click on the right side of the strike symbol with the left mouse button, and then terminate the determination of strike by clicking the other end of the strike symbol with the right mouse button. Note, the “right side” of the strike symbol refers to the right-hand rule for describing strike. It will not necessarily be the east side of the symbol in map view. You will be prompted to input the dip magnitude. The map strike and dip symbol of your digitized attitude will be shown. If you like this determination, then click the **Store Digitized SD Button**, and the XYZ location and strike and dip will be added to the **Field Attitudes Table**. The strike and dip symbol will change to that of a Field Attitude. Similar to Attitudes, these Field Attitudes are only stored in this session of findSD. Exporting or saving from the **File Menu** must be done to record measurements to disk.



Geo map by Mangum and Heller (2022)

Know Bugs

None currently.

Release Notes

v1.10 October, 2023.

Uses Matlab Runtime Library 2023a.

First release to general public.

v1.11 November, 2023.

Uses Matlab Runtime Library 2023a.

No new essential functionality from v1.10. Export attitudes now comma-delimited. Bug fixes include help menu, 3D View dismissing properly, and various plotting and selecting actions.

Potential Future Additions

- Additions to the GUI
- Attitudes posted along a line of section
- Dip domain maps
- Importing of contacts
- Improved editing capabilities
- Improved export capabilities
- Interface with fbffor
- Develop methods of quality assessment of measurements
- Automated calculation of bedding attitudes

References

Connors, Christopher D., Roberts, Hayden, Maloy, Jack, Ogden, Jessie, and Comisac, Parker, 2023, findSD: An application for determination of bedding-plane attitudes from high-resolution digital elevation models, [abs], Geological Society of America Conference, Pittsburgh, PA.

Mangum, H. E. and Heller, M. J., 2022, Geologic map database of the Buena Vista 30- x 60-minute quadrangle adapted in part from Wilkes (2001): Virginia Department of Energy, Geology and Mineral Resources Program, Open-file Report 2022-8, 1:100,000-scale database [Wilkes, G. P., 2001, Geologic map of a portion of the Buena Vista 30- x 60-minute quadrangle, Virginia Division of Mineral Resources Open-file Report 01-01: 1:100,000-scale map. 1:24,000-scale map].

Schwanghart, W. and Scherler, D, 2014, Short Communication: TopoToolbox 2 – MATLAB-based software for topographic analysis and modeling in Earth surface sciences, Earth Surf. Dynam., 2, 1–7, <https://doi.org/10.5194/esurf-2-1-2014>.

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findSD v1.11, November 2023

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