

3D Scan Processing Procedures for Surfer

Instructions Version 1.0
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Pre-processing of Point Cloud

Remove Extraneous Points

The output from most scanners will include parts of the surface that are not of interest, and so it is usually easiest to delete these at the beginning.

Rhino:

- Import point cloud text file into Rhino
 - 'File > Import', select 'Points File' in 'Files of type', and choose file
 - In the Options window, the default Delimiter will usually be correct; if it does not work, open the file in a text editor to work out what type of delimiter the file uses. Check the 'Create point cloud' option.
- It will often be useful to have a polygon surface of the file as well, as this is easier to visualise for alignment and choosing which points to remove. Some scanners/software will produce surface files as well (e.g. stl, dxf), so import these as well. If you only have the point cloud, you can use the boxed procedure below to create a dxf that you can then import into Rhino along with the point cloud.

SurferManipulator:

- Make a grid of the unrotated txt file
 - In 'Utilities > File Format Conversion'
 - Select 'From file type:' 'Text file (irregular, e.g. Hawk)'
 - Select 'To file type:' 'Surfer Grid'
 - In 'Grid' tab, select 'Max. no. rows/cols' and enter '200'
 - Convert *200.grd to dxf to get *200.dxf
 - In 'Utilities > File Format Conversion'
 - From 'Surfer grid file (*.grd)' to 'AutoCAD DXF file (*.dxf)'
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- Import surface polygon file into Rhino into a different layer
 - If the 'Layers' window is not visible: 'Edit > Layers > Edit Layers...'
 - Select a different layer (e.g. Layer 01) by clicking to the left of the layer name so a tick appears in the left hand column.
 - 'File > Import', select relevant surface file type (e.g. stl, dxf) in 'Files of type', and select file (e.g. *200.dxf)
 - Align tooth/tooth row, e.g. anterior/posterior, horizontal occlusal surface
 - Select all objects (Ctrl+A)
 - 'Transform > Rotate' and follow instructions
 - Once alignment is complete, the point cloud must be separated into individual points ('exploded')
 - Select point cloud(s)
 - 'Edit > Explode'
 - Delete all points from exploded cloud from around the tooth

- This can be done by left-clicking and dragging a rectangle around points to select them, or type 'Lasso' in Command line and click and drag an irregular shape around points; then press 'Delete' key
- Export the points to a text file
 - Select all points – either by hiding all other layers (press the light bulb symbol to toggle visible/invisible) and select all (Ctrl+A) or 'Edit > Select Objects > Points'
 - 'File > Export Selected'
 - 'Save as type' 'Points File (*.txt)' and save as '*-a.txt'
 - Choose 'Comma' delimiter, 9 significant digits and uncheck 'Surround values with double-quotes'

Creating, Processing and Manipulating Surfer Grids

Once a 3D point cloud file has been converted to a Surfer grid, many manipulations (blinking, downsampling) can be carried out on the grd file.

General SurferManipulator Settings

SurferManipulator:

- 'Dir' button: Press this to use the default directory. Set the default directory using 'File > Set default directory', navigate to a new directory and click 'Update dir and exit'
- 'Ref' button: Press to refresh the file and directory list on the form

Processing Single or Multiple Files

Most functions in SurferManipulator can be carried out on many files at once. If you choose a file from the file list and select a function (e.g. Blank) then just that file will be processed. However, you can choose multiple files to be processed in the same manner with the same settings. The files to be processed are added to a filename list either individually or for all files in the directory.

SurferManipulator:

- To process multiple files
 - Either 1) Select the first file, click 'Add filename' (or double-click), select second file, click 'Add filename' (or double-click), etc.
 - Or 2) Click 'Add all filenames', which adds all files listed in the file box
 - The number of files added to the filename list is shown next to the 'No. files' label.\
- To clear the filename list, click 'Clear filenames'
- If you would like to run the same procedure on the same filename list several times, uncheck the 'Clear filenames after fn' button. Once the function is run, the filename list is maintained.

Convert to Surfer Grid

SurferManipulator:

- Create Surfer grid file (*.grd) from the txt file using 'Utilities > File Format Conversion' function
 - For 'From file type:' select 'Text file (irregular, e.g. Hawk) (*.txt)'
 - For 'To file type:' select 'Surfer grid file (*.grd)'
 - All main options are given in the 'TXT to GRD' tab
 - Select 'Grid intervals' and enter output grid resolution (distance between grid points) in same units as the text file (e.g. if text file is in mm, enter '0.02' for 20 µm)
 - Use 'Kriging' as 'Gridding method' (default)
 - If the 'Create blanking outline' option is checked, the output will be a blanked Surfer grid file ('*pb.grd'). If the 'Remove undercuts' option is also selected, the final file

will be named similar to: '*-uct48_12pb.grd' This final grid is blanked, so that only the tooth surface remains in the grid.

○ **Remove Undercuts in Joined or Realigned Scans**

- For full 3D scans, the point cloud must be turned into a 2.5D scan, i.e. only the surface visible from above (along the z axis) is present in the file, and there are no undercuts
- If undercuts need to be removed, check 'Remove undercuts' option
- If the 'Use default settings' option is checked, then it will calculate the required statistics from the grid intervals value. However, the detailed options are available on the 'UC and blank' tab, and are explained below
- Primary Search Radius should be slightly above half of the resolution at which the scan the scan was made and will be interpolated onto a regular grid, e.g. if make a grid of 20 × 20 µm resolution in Surfer, Primary Search Radius should be about 12 µm. If undercuts appear in the gridded file, then increase the search radius to, say, 15 µm. The default settings give a threshold of 4 times the search radius, so if search radius is 12 µm, then threshold is 48 µm.
- Outputted file will have extension '-uct' + threshold + '_' + search radius; e.g. '-uct048_012'; a file with the rejected points will also be created, ending in '_rej'
[Note: old format for undercut file is: '_t' + threshold + ',' + search radius; e.g. '_t0.04,0.010']

○ **Automatically Generate Blanking File**

- If the tooth was cut out at point cloud stage (file name ending '-a'), then this option can be used to automatically create a Surfer blanking file that will isolate the area of interest
- To automatically generate a blanking file before creating Surfer grid, check 'Create blanking outline' option
- If the 'Use default settings' option is checked, then it will calculate the required statistics from the grid intervals value. However, the detailed options are available on the 'UC and blank' tab, and are explained below
- The resolution ('Bin size') at which the program will draw a blanking line around the point cloud should be roughly 1.5-3 times the resolution that the point cloud will be gridded at and the original surface was scanned at (e.g. 0.05 if gridding at resolution 0.02). The result is a blanking file '*pblnpts.bln' that can be used to blank a grid
- Check 'Create points file with points in blanked area'. This creates a new txt file with an extension 'p' that has points distributed in the area outside the tooth. This reduces the time that it takes for Surfer to create a grid from the txt file

Plotting in Surfer

Visualisation of the Surfer grid can be done in a Surfer Plot window

SurferManipulator:

- Plot Relief Map of grid using 'Utilities > Surfer Functions > Plot grid' function
 - Select the grid to plot
 - Select required plot type (default is Relief map) and options
 - Click 'Plot grid'

Blanking in Surfer

If it is necessary to remove parts of a Surfer grid (for example, to remove non-tooth parts of the grid or to isolate a single tooth) then the file must be 'blanked' in Surfer. If the 'Create blanking outline' option was used when the txt file was converted to Surfer grid, then this step is not necessary.

SurferManipulator:

- Blank the area outside the tooth using 'Utilities > Surfer Functions > Digitise and blank grid' function
 - Either 1) If tooth has been cut out of point cloud (file name ending '-a...p') then:
Make sure the '*pblnpts.bln' file is in the same directory as the grd file
Check 'Use existing bln file' with 'Del. no. char. from grd fname' = 0
Click 'Blank'
 - Or 2) If tooth was not cut out of point cloud then:
Click 'Blank' and follow instructions on screen

Mirror Left Side (for MorphoBrowser)

Move all grd files from left side of jaw (*-ul* and *-ll*) into a directory called 'left not mirrored'

SurferManipulator:

- Mirror the grids in the x-plane using 'Utilities > Surfer Functions > Process grid' function
 - Select 'Mirror' and 'X' and click 'Process'
 - Move mirrored files (*.mx) back into the same directory as the files from the right side of the jaw

Standardising Resolution of Scans (Downsampling)

In order to run OPC analyses, it is best to standardise the resolution of scans to make results more comparable. This procedure will re-grid the data to an exact number of data rows.

SurferManipulator:

- Either 1) If tooth has been cut out of point cloud (file name ending '-a...p'), then
 - Copy the *pblnpts.bln file into same directory as the *p.txt file
 - Use 'Utilities > Surfer Functions > Regrid at exact resolution' function, select 'Use txt files', and set the 'Exact no. rows/cols' to 150. (Must change file types shown to 'Hawk text file (*.txt)' rather than 'Surfer grid file (*.grd)' in order to select txt files from file list box.) This will generate three directories: b150_grd, b150b_grd and b150b_dat
 - For this method, you will need to mirror the resulting '150' files.
- Or 2) If the tooth was manually blanked using Surfer, then
 - Copy the *blnpts.bln file into the same directory as the *b.grd file
 - Use 'Utilities > Surfer Functions > Regrid at exact resolution' function, select 'Use grid files', set 'Del from grd filename' = 1, and set the 'Exact no. rows/cols' to 150. This will generate three directories: b150_grd, b150b_grd and b150b_dat.

Blanking Individual Teeth

To carry out analyses of individual teeth, the teeth can be separated into different Surfer grids.

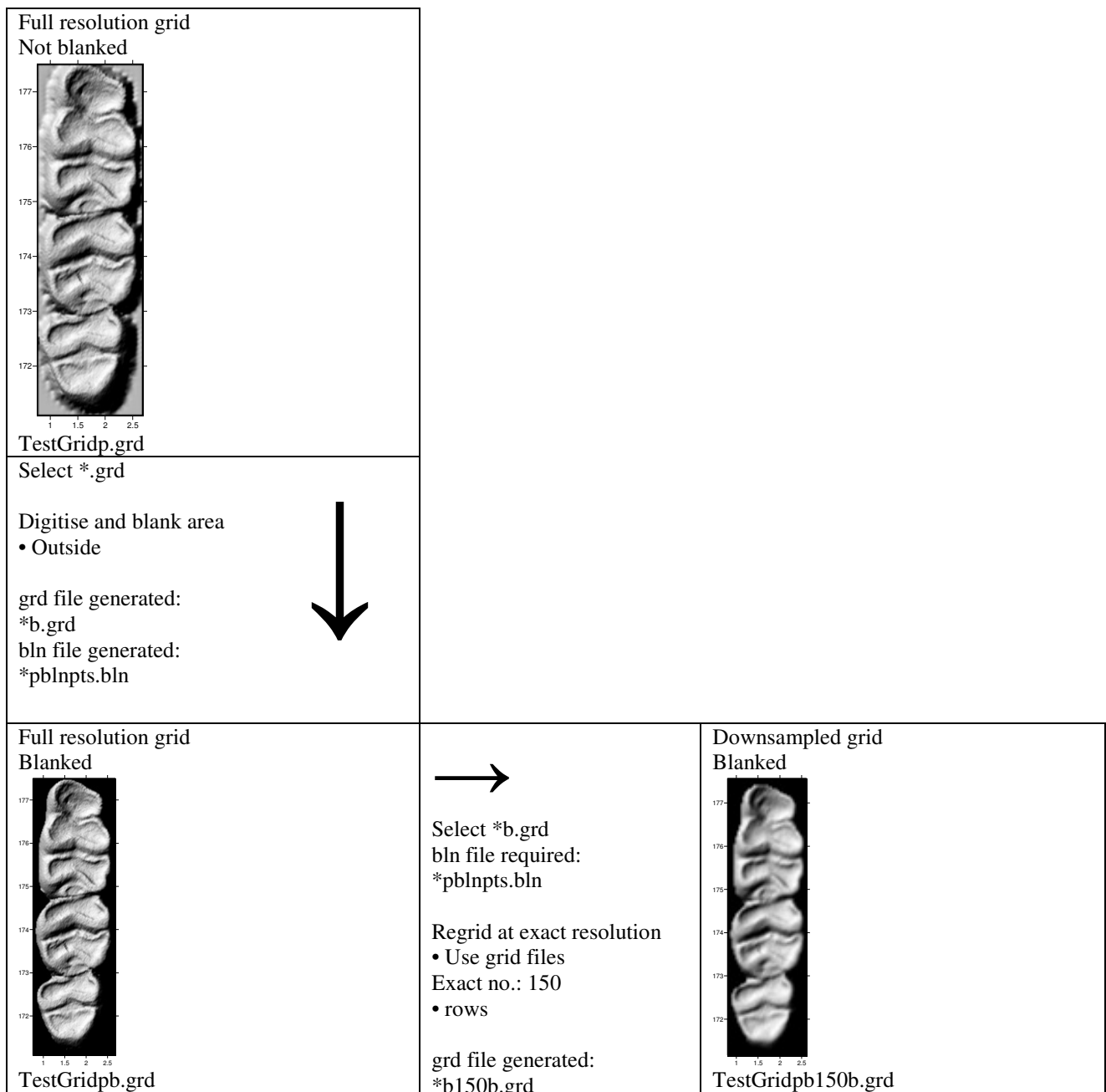
SurferManipulator:

- Blank the borders between individual teeth using 'Utilities > Surfer Functions > Digitise and blank grid' function
 - Select file to process
 - Check 'Multiple teeth' in the 'Digitise and blank grid' frame

- Check the teeth to be blanked, e.g. for teeth P4, M1 and M2, check only the boxes 'p4', 'm1' and 'm2'
- Click 'Blank'
- Digitise the required number of borders between teeth. Do the most anterior border first (greatest y value). Draw the border from left to right, starting outside the grid area. Between each border, type '-1' into the 'digit.blm' window on a new separate line. Do not put a '-1' at the end of the file
- Save the file as 'digit.dat'
- Click 'OK'

Combination Downsampling and Individual Teeth Blanking

To carry out OPC analyses on individual teeth, it is necessary to standardise the resolution of the separate teeth, either to be the same as the downsampled whole tooth row or the same number of rows for each tooth. The following table gives directions and settings to be used in the 'Digitise and blank grid' and 'Regrid at exact resolution' functions in SurferManipulator. Follow the arrows to convert from one type to another.



Select *.b.grd

Digitise and blank area

- Multiple teeth
- m1 m2 m3

grd files generated:

- *pb-sm1b.grd
- *pb-sm2b.grd
- *pb-sm3b.grd

bln files generated:

- *pb-sm1blnpts.bln
- *pb-sm2blnpts.bln
- *pb-sm3blnpts.bln



Full resolution separated teeth grids

Blanked

TestGridpb-sm1b.grd

Select *b-sm1b.grd, *b-sm2b.grd, *b-sm3b.grd

bln files required:

- *pblnpts.bln
- *pb-sm1blnpts.bln
- *pb-sm2blnpts.bln
- *pb-sm3blnpts.bln

Regrid at exact resolution

- Use grid files
- Indiv. teeth (multi teeth blanked)

Exact no.: 50

- rows (Y)

grd files generated:

- *pb-sm1b50b.grd
- *pb-sm2b50b.grd
- *pb-sm3b50b.grd



Downsampled separated teeth grids

- all teeth same no. rows (e.g. 50,50,50)

Blanked

TestGridpb-sm1b50b.grd

Select *b150b.grd

bln files required:

- *pblnpts.bln
- *pb-sm1blnpts.bln
- *pb-sm2blnpts.bln
- *pb-sm3blnpts.bln

Digitise and blank area

- Multiple teeth
- m1 m2 m3
- Use existing bln file

Del. no. char. from grd fname: 5

grd files generated:

- *pb150b-sm1b.grd
- *pb150b-sm2b.grd
- *pb150b-sm3b.grd



Downsampled separated teeth grids

- teeth same resolution as in row (e.g. 80,50,20)

Blanked

TestGridpb150b-sm1b.grd