Course: TERRA Summer School – Module II – Remote Rock Mass Characterization

Exercise: Roughness measurement and digitization of roughness profile

Course instructors: D.Sc. (tech.) Lauri Uotinen, Dr. Mateusz Janiszewski

Roughness measurements

Asperity measurements – small scale roughness of rock joints

Asperity (roughness) is typically measured 2D in the direction of the presumed movement. If the movement direction is not known, then in the direction of the dip (= the direction where water would flow is placed on the surface). In this exercise, we will use CloudCompare to extract a 2D curve, and then use analytical method (regression equation) to compute the JRC value and range.

Your task is to measure roughness of the following fracture surface (yellow line indicates roughness profile location):

Note: This step-by-step guide is written for the demonstration of the method in the video tutorial. In your assignment question, the location and grid data points are slightly different, hence the Z2 and resulting JRC range will be different. However, the methodology is the same and you will be provided with the necessary grid points for the profile direction as well as the POLY file format for your roughness profile line. Please follow the video attentively!

Figure 1 - Joint surface location

Figure 2 - Close up of joint surface

- The red box indicates the joint surface where roughness will be measured.
- The yellow line indicates the profile direction where roughness profile will be extracted.
- The dedicated joint surface has been segmented into a smaller point cloud as seen on the left side.

Step-by-step instructions

1. Open **CloudCompare** (the guide was written for version v2.12.4 (Kyiv) [64 bit]). You can download a **stable release** from this link: [CloudCompare - Downloads (danielgm.net)]
2. Import the **BIN file** (BIN file for roughness exercise) into CloudCompare. You can do this in the following ways:
   - Click on File -> Open -> Click on the BIN file and open
   - Click on the icon 
   - Drag and drop the BIN file into CloudCompare

Note: If you cannot see the model, click on the **'global zoom'** icon. 

3. The BIN file already has the **'segmented joint surface'** from the original model which can be seen on the left side of the GUI in the DB (database) tree. Segmentation of the concerned joint surface is the first essential step in the digitization of 2D roughness profile. It's done via the **'segment'** tool and then clicking points on the point cloud where we want to segment it. 
4. The second step is **levelization of the surface**. First, we need three grid points in a right-angle format on the segmented joint surface as shown in Figure 3.

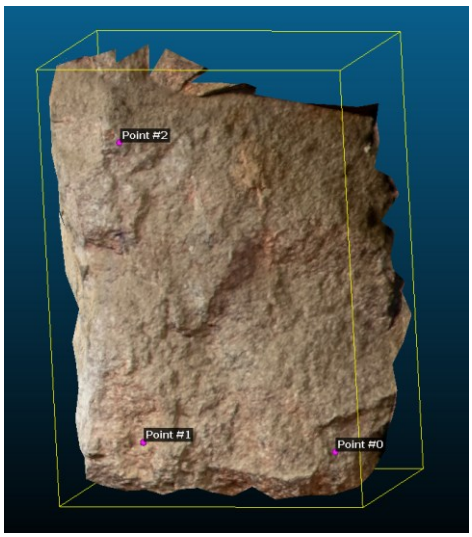


Figure 3 - Grid data points for levelization of segmented joint surface

To do this, make sure the segmented point cloud is checked (S30-S40 segmented point cloud) and then click on **'point list picking'**  . A small new window will open and click three points on the point cloud as shown in the figure above. You can save the points file for later use by clicking  Use the dropdown arrow and click label name, x, y, z and save it as 'picking_list'.

Note: In your assignment, the picking list has already been made for you as a text (txt) file. You just need to import the text file into your model after which you'll see the points where you need to click for the levelization step.

5. Now that you have the three points for visual reference, click on the icon  on the left side of the GUI (pick three points on the floor plane). Uncheck the mesh file and check the point cloud file as this will be the one you are leveling. With the point cloud checked, click on point 0 and then point 1 and point 2 finally. Try to click exactly on the grid points shown above in Figure 3. (Try to rotate the point cloud, so that you can view it as in Figure 3).
6. After levelization step, the point cloud needs to be **rasterized** in the specific sampling interval. Click on the levelized point cloud and then click on  in the tool bar at the top. It will open a new panel. In the **'Grid'** menu, input '**0.001'** as the **'step'**. In the **'projection'** menu, input the **'direction'** as **'Z'**. Then press the red colored bar **'update grid'**. You will see a preview of the rasterized point cloud on the right-hand side of the panel. Finally in the **export** tab, click on **'cloud'** which will create a new rasterized point cloud with the sampling interval of 1 mm.

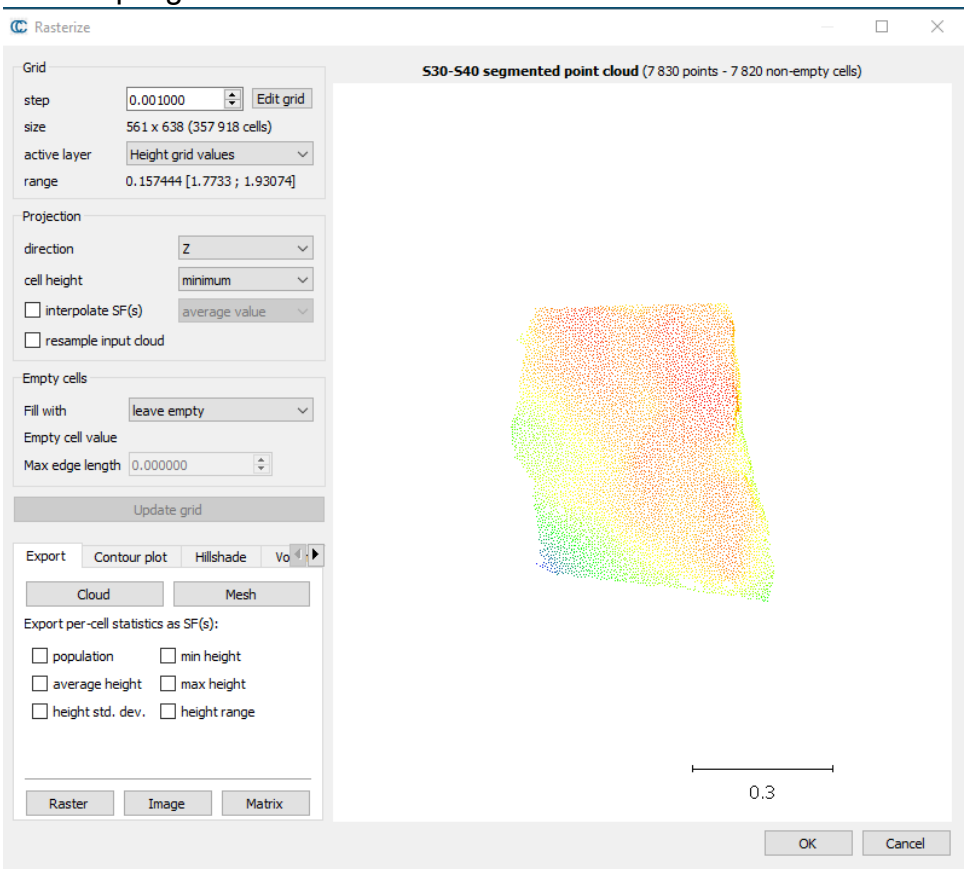


Figure 4 - Rasterized point cloud settings

Note: If you cannot see the point cloud, then you can increase the point size of the point cloud to your preference. Click on the segmented point cloud -> Properties -> Point size

7. The next step is to draw the roughness profile. For that, **two grid points** are needed on the point cloud. The grid points can be chosen exactly as in the levelization step and then saved as text file. Using the coordinates of those two grid points, another text file (POLY file) can be generated for the roughness profile direction.

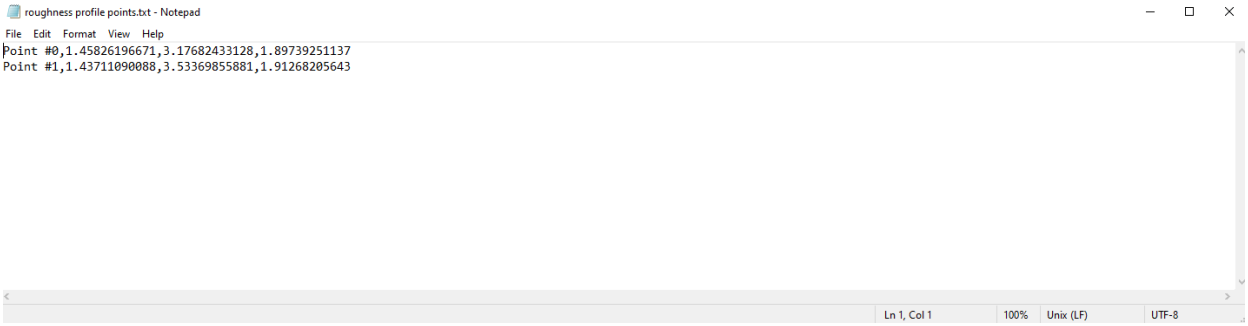


Figure 5 - Grid points for roughness profile start and finish

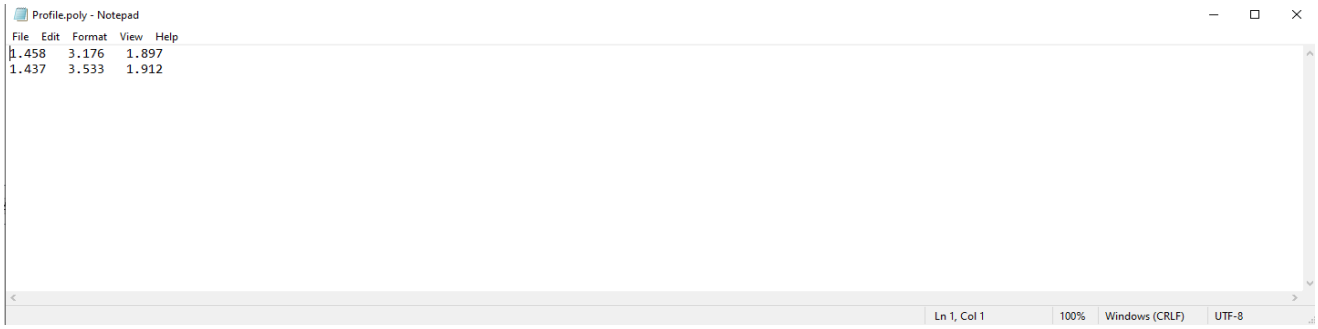


Figure 6 - Roughness profile polyline

Note: The text file (POLY file) for the roughness profile can be generated in a notepad with the first column as X, second column as Y and third column as Z coordinate with a tab separating them. You can copy the coordinates from the two grid points (start and end of profile) generated earlier. Copy only upto three decimal points. (For the purposes of the assignment, you will already be provided with grid points text file and a POLY file but you will need to copy the coordinates from the grid points into the POLY file for the generation of roughness profile as shown in the video tutorial). The roughness profile will act as a polyline on which the points will be extracted for the roughness calculation. Import the POLY file with the coordinates into cloudcompare to see the polyline for the profile.

a b

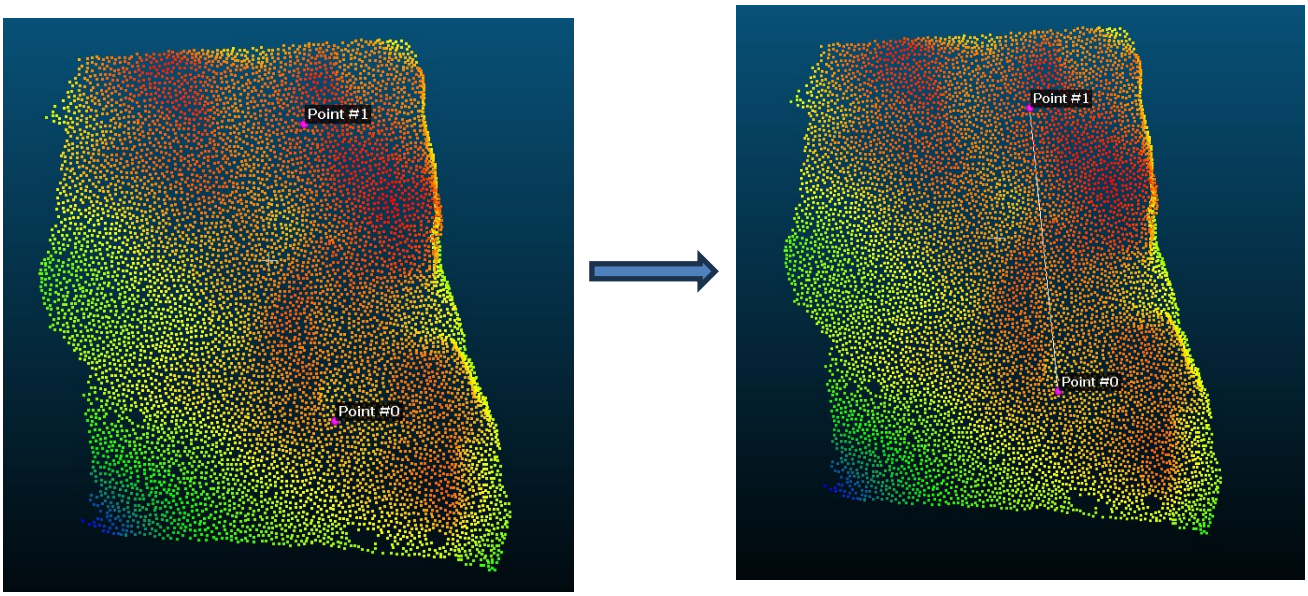
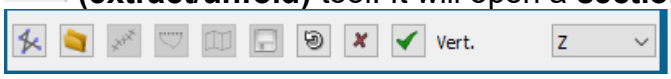


Figure 7 - a) Grid points indicating start and end of profile. b) Polyline indicating roughness profile

8. Finally the generation of **roughness profile** can be done by checking the rasterized segmented point cloud.raster (0.001) and then clicking on the icon  **(extract/unfold)** tool. It will open a **section edition mode** 

. Click on the first icon to enable the '**polyline creation tool'**. Then click on the '**folder icon'** to import a polyline from the DB tree. Since we have already imported the polyline file earlier, we will see a polyline available in the **'Selection'** window. Click on that and a new red colored line will appear on the point cloud. This line acts as a reference line for the generation of roughness section and extraction of points will be done along this reference line. After this click on the **'Extract points along active sections'**, a new popup window will appear and keep all the default settings and press OK. Keep the **vert. as Z** and then click on the **'tick'** icon to close the **section edition mode**.
9. Now a **digitized roughness profile** will appear along the profile line which you can inspect and zoom in. To see it clearly, uncheck all other components in DB tree and keep the 'section envelope#1' checked.

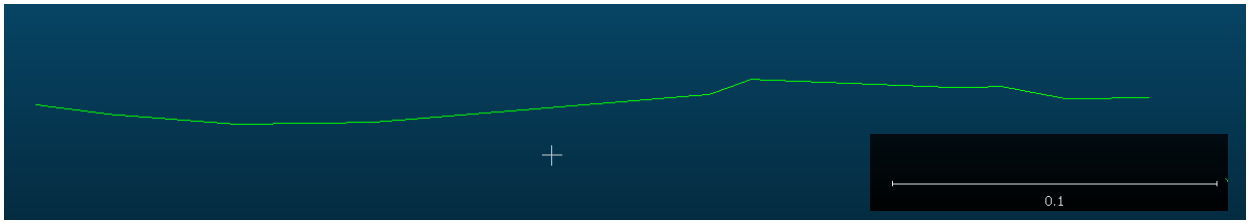


Figure 8 - Digitized roughness profile

10. For the calculation of Z2 and JRC with analytical means, you have to save the **'Section envelope#1'** file. Click on the save icon  while having the section envelope checked. Save the type as 'Height profile (.csv)' file in a folder of your choosing.
11. In the excel file, you'll only see one column with two sets of values written together. Click on that column, then go to '**Data tab'** and select '**text to columns tool'** from the '**data tools section'**. Keep the option **'delimited'**, press next and use the **'semicolon'** delimiter and uncheck the tab option. Press next and then finish. The calculation of Z2 and JRC can be done by the following steps in excel:
    - In the C column, use the operation: C3 = A3-A2 and then drag the operation to the other values.
    - In the D column, use D3 = B3-B2
    - In the E column, use E3 = (D3/C3)^2
    - Sum the values of E column, =sum(E3:EXXX)
    - Calculate Z2 as, =SQRT(sum(E3:EXXX)/Now of rows – 1 (Note: count the rows from where the values start. Ignore the header line)
    - Now calculate JRC. Use Tatone Bryan (1.00 mm) regression equation as the rasterization was based on this specific regression model. You can find the equation from below.

Author	Regression equation	Interval	Year
Tse R. and Cruden D.M.	$JRC = 32.2 + 32.47 \cdot \log_{10} Z_2$	1.27 mm	1979
Yu X.B. and Vayssade B.	$JRC = 60.31 \cdot Z_2 - 4.51$	0.25 mm	1991
	$JRC = 61.79 \cdot Z_2 - 3.47$	0.50 mm	
	$JRC = 64.22 \cdot Z_2 - 2.31$	1.00 mm	
Yang Z.Y., Lo S.C. and Di C.C.	$JRC = 32.69 + 32.98 \cdot \log_{10} Z_2$	0.50 mm	2001
Tatone Bryan S.A. and Grasselli G.	$JRC = 51.85(Z_2)^{0.60} - 10.37$	0.50 mm	2010
	$JRC = 55.03(Z_2)^{0.74} - 6.10$	1.00 mm	

Figure 9 - Z2 and JRC relationship (source: Summary of Suggested Relationships between Z2 and JRC of Previous... | Download Table (researchgate.net))

Formula for Z_2 (Tse and Cruden, 1979)

$$Z_2 = \sqrt{\frac{1}{M}\sum_{i=1}^{M}\left(\frac{z_{i+1}-z_i}{x_{i+1}-x_i}\right)^2}$$

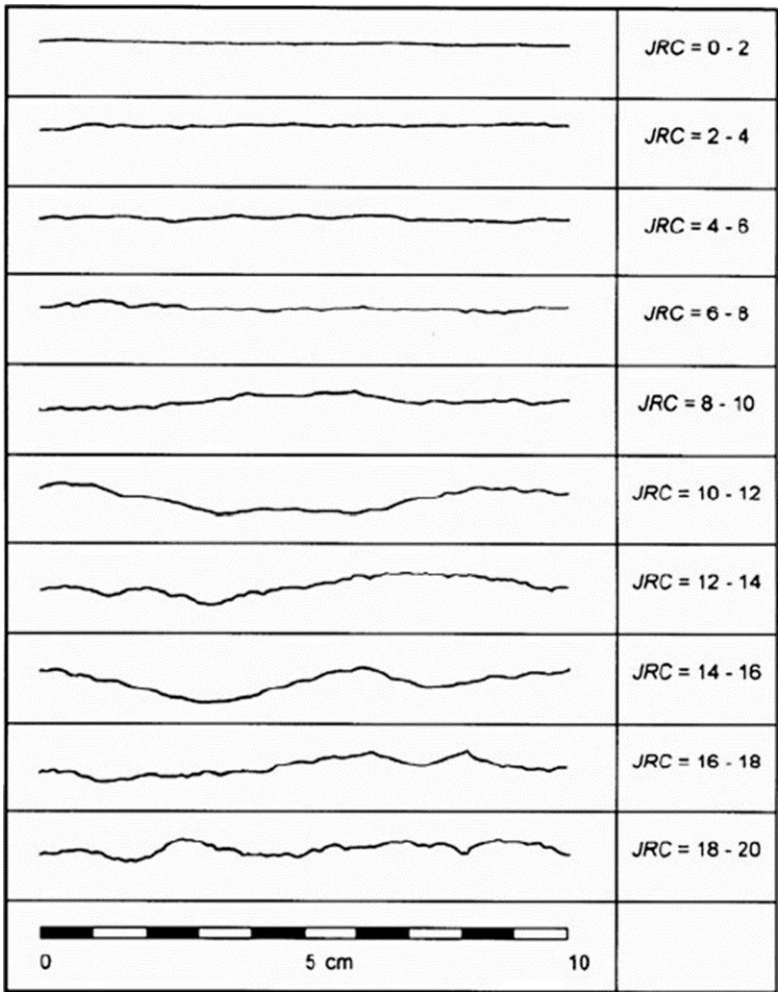


Figure 10 - JRC model curves (source: Barton and Choubey, 1977)