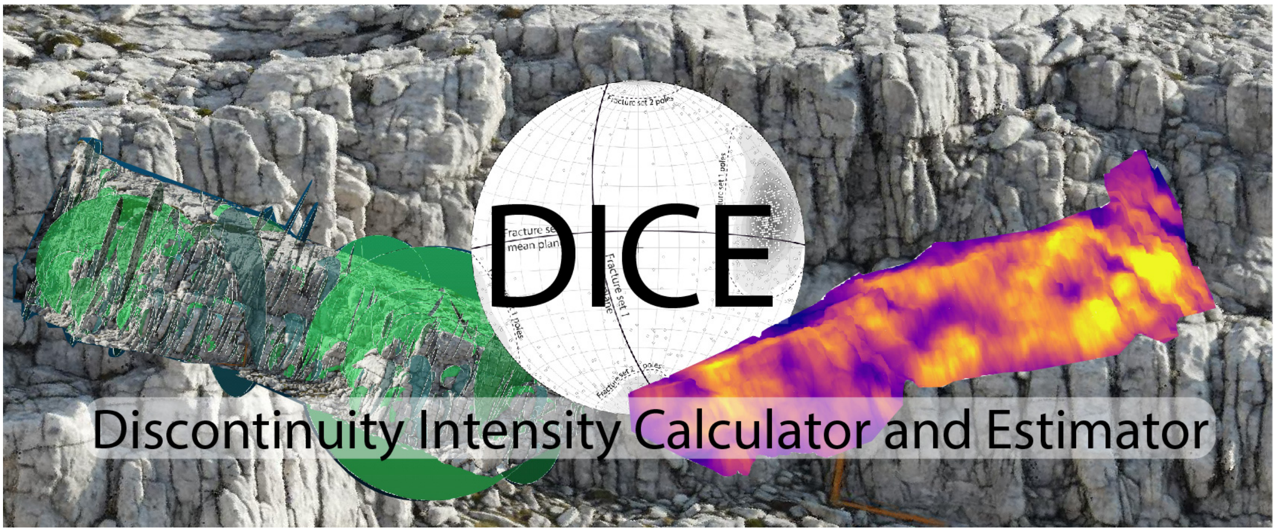

USER MANUAL
of

DICE v.1.0 beta

Update at 22th November 2021

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Preface

This user manual describes how to use Discontinuity Intensity Calculator and Estimator (DICE) MATLAB-app.
The App uses the point cloud of a Digital Outcrop Model and the 3D mapped discontinuity information to calculate and estimate the fracture intensity and other fracture parameter, taking into account the local orientation of the slope and the position, dimension and attitude of the mapped discontinuity planes.
Here we refer to discontinuity, because DICE app is not limited only to the investigation of the fracture network but can be used for each kind of geological planes (bedding, foliation, etc.).
The DICE app uses different kinds of discontinuity sampling technique – (1D)scanline, (2D)scanwindow and (3D)scansphere - and therefore, can calculate and estimate the linear, areal and volumetric fracture intensity. Moreover, using some sampling approaches it can be possible to calculate the discontinuity spacing, the Mean Trace Length (MTL) and the Rock Quality Designation (RQD) index.
In the next pages, all the steps necessary for the application of the DICE app will be described.
A detailed explanation of the DICE algorithm will be available in Menegoni et al. 202X (in preparation) (doi: available in future).

Important message! To use the DICE app, you will need about the Computer Vision Toolbox and the Parallel Computing Toolbox of MATLAB.

1) Input data formatting

The input data of the ROKA algorithm are (1) the point cloud with point colors (RGB) representing the rock outcrop and (2) the geometric information about the 3D mapped discontinuities.

(1) The point cloud must be a text files (.txt) containing a series of row where the *x*, *y* and *z* point coordinates and the R, G and B color components (255 format) must be defined for each point of the point cloud. The information must be order as *x*, *y*, *z*, *R*, *G*, *B* and must be delimited by space. It is very important to use point cloud referenced in a metric Coordinate System (CS), it can be a local CS or geographical one.

(2) The geometric information about the 3D mapped discontinuities must be stored in a xlsx file and must contain at least 9 headed columns regarding dip and dip direction angles, the radius of the discontinuity, the x, y and z coordinates of the center of the discontinuity and the Nx, Ny and Nz components of the discontinuity plane normal vectors. As depicted in Fig. 1, the headers must be named as *Dip*, *DipDirection*, *Radius*, *Xcenter*, *Ycenter*, *Zcenter*, *Nx*, *Ny* and *Nz*, and can be reported in any order.

	A	B	C	D	E	F	G	H	I
1	Dip	DipDirection	Radius	Xcenter	Ycenter	Zcenter	Nx	Ny	Nz
2	75.53006506	280.8878178	1.009687331	2.208042347	0.623653595	2.583200379	-0.950848801	0.182894962	0.249871949
3	71.41251497	325.0037196	0.207667121	1.346377834	0.268328049	1.318149248	-0.543607169	0.776458774	0.318752283
4	78.76489368	185.250972	0.232006173	1.556653469	0.381592091	1.301972578	-0.089764648	-0.976719759	0.194835367
5	49.73138137	65.55483395	0.228861197	1.496707797	0.291602003	1.451664356	0.694623401	0.315755628	0.646371963
6	68.89567521	327.7119376	0.382386526	1.731894681	0.377758194	1.335610071	-0.498347083	0.788670892	0.360067228
7	72.12530208	321.4383458	0.192776178	2.274439931	0.436530083	2.280219555	-0.593267027	0.744193728	0.306936359
8	60.48743569	223.0855	0.150597688	2.17931962	0.431472167	1.868270993	-0.594456598	-0.635572497	0.492614407
9	69.3630168	301.5186076	0.843450118	2.346786197	0.313290482	1.506104373	-0.797769308	0.489230112	0.352445781
10	75.9207624	305.7636221	0.43957799	2.467719913	0.075353235	1.004101008	-0.787059732	0.56688608	0.243263541

Fig. 1 Example of the format of the Excel file containing the geometric information of the 3D mapped discontinuities.

Option to create the discontinuity information Excel file:

i. In the main folder of the algorithm is present a script, called '*dxf_plane_fit.m*', that is able to fit a 3D disc and extract a Excel file with all the information required by ROKA, from a dxf file that contains all the discontinuity traces mapped onto the 3D model.

ii. using the Cloud Compare open-source software, there are several way to map the discontinuities (e.g. tool Trace Polyline; plugin Compass developed by Thiele et al., 2017), find their best-planes (e.g. tool-->Fit-->Plane) and then export the best-fit planes information (tool-->Batch Export--> Export plane info).

The main problem with the second method is that it fits to the mapped discontinuity a 3D planar rectangle and, therefore, the 'radius' of the Beacher's discs, that represent the discontinuity and that is required by the ROKA algorithm, is not calculated. To achieve the radius, the authors suggest to use the Pithagoras' Theorem to calculate the max extension of fitted rectangle and consider it as the diameter of the discontinuity Beacher's disc. Therefore, for example it is possible to calculate the radius from the height and width of a rectangular best-fit plane using the formula:

$$radius = \frac{\sqrt[2]{(length^2 + height^2\ )}}{2}$$

where *radius* is the radius of the Beacher's disc representing the discontinuity, *length* is the length of the rectangular best-fit plane and *height* is the height of the rectangular best-fit plane. This calculation could be done in a very simple way using spreadsheets.
The data will be load during after the launch/start/run of the code.

In some cases, you will need for the discontinuity set information. In particular:
(3) an excel file where the set belonging of each discontinuity must be prepared specifying for each disconinuity its dip, dip direction and set belonging. The header must be named as ‘Dip’, ‘DipDirection’ and ‘Set’. The order of the discontinuity/fractures must be the same of the previous excel file containing their geometric information (the DICE app generate an ID for each discontinuity according to its row position in the excel file, therefore, the ID for each discontinuity must be the same in the two different files). See the example in Fig. 2.

	A	B	C	D	E	F	G	H	I
1	Dip	DipDirection	Set						
2	75.53006506	280.8878178	5						
3	71.41251497	325.0037196	5						
4	78.76489368	185.250972	3						
5	49.73138137	65.55483395	1						
6	68.89567521	327.7119376	5						
7	72.12530208	321.4383458	5						
8	60.48743569	223.0855	3						
9	69.3630168	301.5186076	5						
10	75.9207624	305.7636221	5						

Fig. 2 Example of the format of the Excel file containing the set belonging information of the 3D mapped discontinuities

To create this file consider to use some sterographic projection software as Stereonet (http://www.geo.cornell.edu/geology/faculty/RWA/programs/stereonet.html) or Dips

(https://www.rocscience.com/software/dips). In the future will be probably added the possibility to define the discontinuity set directly in the DICE app.
(4) an excel file containing the mean orientation of each discontinuity set. The headers must be named as 'Set', 'Dip' and 'DipDirection'. See the example in Fig. 3.

	A	B	C
1	Set	Dip	DipDirection
2	1	40	54
3	2	88	154
4	3	55	196
5	4	54	251
6	5	72	303

Fig. 3 Example of the format of the Excel file containing the mean orientation of the discontinuity sets.

(5) one or more DXF files representing the 3D scanlines must be stored in a folder. Each scanline must be defined by only two point, the starte and end points, and must be saved as a single dxf file. The folder that contains the dxf files of the scanlines, must not contain other files. This because during the scanline sampling calculation, the DICE app try to read and load as scanline each single file in the folder containing the scanline.

2) How to use DICE app

You can use the DICE app in two ways:

- download the installation file and install the app. It will appear onto the app panel of the MATLAB software.
- download the DICE_application folder, open the DICE.mlapp (with MATLAB) and run it.

Then the DICE interface will appear (Fig. 4).

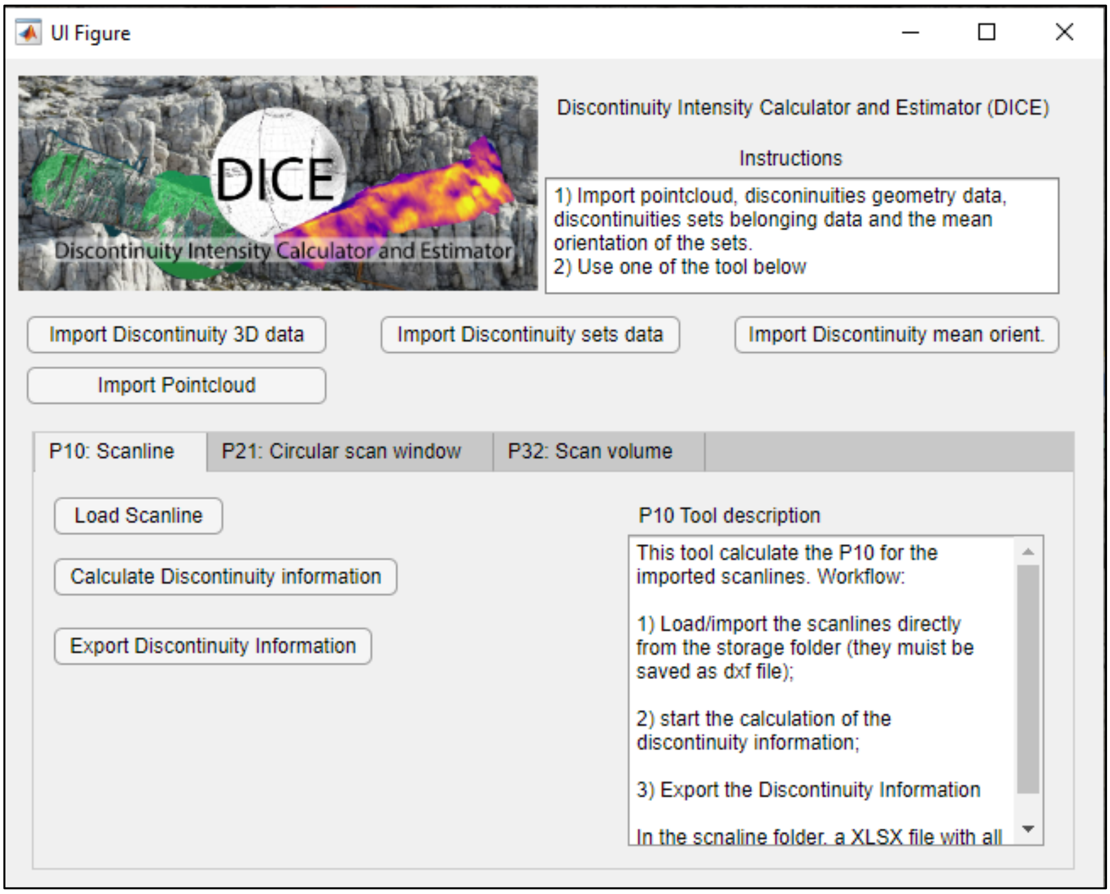

Fig. 4 DICE app interface. In the upper part the input files loading buttons. In the lower part the P10:scanline, P21:Circular scan window and P32: Scan volume panels include the calculation and exportation buttons.

2.1) P10:Scanline

To use the P10:Scanline sampling strategy you will need about the geometric information of the fractures (example in Fig. 1), their set belonging (example in Fig. 2) and the mean orientation of the files (example in Fig. 3). Moreover you will need about a folder containing one or more dxf file containing the 3Dscanlines, no other files must be inside this folder. The point cloud is not necessary but can be used to visualize the results of the scanline sampling process.

Then start to import the input files:

1) the 3D geometry information of the discontinuities can be loaded clicking on the 'import Discontinuity 3D data' button and selecting the excel file;
2) the set belonging information of the discontinuities can be imported clicking on the 'Import Discontinuity sets data' button and selecting the correct excel file;
3) the mean orientation of the discontinuity set can be imported clicking on the 'Import Discontinuity mean orient.' button and selecting the correct excel file;
4) the point cloud can be imported clicking on 'Import Pointcloud' button and selecting the *.txt* file that defines the point cloud;

Then select the P10: scanline panel and import the 3D scanline/s clicking on the 'Load scanline' button and selecting the folder that contains the dxf file/s of scanline/s.
To perform the scanline sampling strategy click on the 'Calculate Discontinuity Information' button and, then, export them by clicking on the 'Export Discontinuity Information' button.
The results of the calculation will be stored in an excel file in the scanline folder. In this file for each scanline it is reported the name of the scanline, its length, number of intersected discontinuities, P10 (linear discontinuity intensity), the number of discontinuity intersected for each set, the mean and median spacing of each set and the RQD value (see example in Fig. 5)

	A	B	C	D	E	F	G	H	I	J	K
1	Row	SL_length_n	N_Fractures_tc	N_P10	N_Sets_intersecti	N_fractures_set	N_fractures_set	N_fractures_set	N_fractures_set	N_fractures_set	N_fractures_set
2	SL1.dxf	6.42048487	21	3.270781014	4	0	4	1	5	11	0
3	SL10.dxf	2.34064215	13	5.554031405	3	0	1	1	0	11	0
4	SL2.dxf	5.32578274	5	0.938829135	2	0	0	0	2	3	0
5	SL3.dxf	3.30211112	9	2.725529118	4	0	2	1	4	2	0
6	SL4.dxf	3.78471794	15	3.963307242	4	0	2	3	3	7	0
7	SL5.dxf	2.20210451	18	8.173998971	4	0	5	3	2	8	0
8	SL6.dxf	4.02726278	7	1.738153279	2	0	0	1	0	6	0
9	SL7.dxf	2.3511226	12	5.103944816	5	1	0	1	6	3	1
10	SL8.dxf	2.33714191	9	3.850857305	4	0	1	1	2	5	0
11	SL9.dxf	2.49866174	12	4.802570828	3	0	1	1	0	10	0

L	M	N	O	P	Q	R	S	T	U	V	W
Smean_set	Smean_set2	Smean_set3	Smean_set4	Smean_set5	Smean_set	Smedian_set	Smedian_set	Smedian_set	Smedian_set4	Smedian_set	RQD
0	0.947968624	0	0.838140235	0.49651024	0	0	0.897637933	0	0.821874657	0.287659346	94.6565055
0	0	0	0	0.215657985	0	0	0	0	0	0.161999223	82.8765342
0	0	0	5.52455E-07	2.466429961	0	0	0	0	5.52455E-07	2.466429961	99.4421291
0	0.092557477	0	0.497160285	0.546575119	0	0	0.092557477	0	0.549003241	0.546575119	99.5664685
0	1.073578655	0.158231179	1.036507488	0.375854447	0	0	1.073578655	0.158231179	1.036507488	0.327402895	92.7221628
0	0.152512971	0.162120695	0.107372123	0.265346862	0	0	0.152174138	0.162120695	0.107372123	0.229007469	80.8514291
0	0	0	0	0.377583598	0	0	0	0	0	0.289712733	98.2399837
0	0	0	0.220242125	0.35442699	0	0	0	0	0.238168153	0.35442699	94.0699663
0	0	0	0.011889036	0.35430186	0	0	0	0	0.011889036	0.128424511	97.8471826
0	0	0	0	0.201930523	0	0	0	0	0	0.206836859	92.6622184

Fig. 5 Example of the excel file containing the output results of the scanline sampling approach.

2.2) P21: Circular scan window

The P21: Circular scan window sampling strategy can be use manually, selecting the position of the circular scan window, or automatically in each position of the point cloud, using a moving-scan window. To use both the strategies the user must be open the P21: Circular scan window panel.

2.2.1) For the manual sampling strategy, it is required to import the point cloud, the geometric information of the discontinuities (e.g. Fig. 1) and their set belonging (e.g. 2).
Then the radius of the circular scan window must be defined in the 'CW radius' spinner window (the default value is 1 meter).
Then click on 'Select the center of CW' to pick the center of the scan window directly onto the point cloud. After the picking, a message will appear on the MATLAB command window asking if the selected point is correct or if you want to select another point. To proceed reply as Y (yes) or N (no).
Then, when the picked point is confirmed, DICE fits the circular scan window onto the point cloud. Similarly, to the previous step, the scan window must be confirmed.
Then, to export the results the 'Export parameters' button must be clicked. DICE app will plot the sampling results in some figures and will report the calculated parameters onto the Command Window of MATLAB.
2.2.2) For the automatic sampling strategy, it is required to import the point cloud and the geometric information of the discontinuities (e.g. Fig. 1). Then the circular scan windows radius must be defined using the spinner window (default value is 1 meter). Then, the automatic calculation of the P21 can be launched clicking on the 'P21 point cloud' button. This process can take some time, because for each point of the cloud select the neighbor points inside the scanning radius, fit the circular scan window, identify the discontinuities that intersect the scan window and perform the discontinuities parameters calculation.
The results of the automatic sampling strategy will be stored as a point cloud file into a new folder, created in the same path of the input point cloud.

2.3) P21: Circular scan window

The P32: Scan volume sampling strategy can be used only in the automatic way. The input files required are the point cloud and the geometric information of the discontinuities (e.g. Fig. 1).
After the importation of the input files, the radius of the scan volume (sphere) must be defined using the spin window in the P32: Scan volume panel. After the definition the scan radius, the calculation can be launched using the 'Calculate P32' button.
Similarly to the P21: Circular scan window automatic sampling approach, the results of the P32 calculation are embedded into a point cloud stored in a new folder created in the same path of the point cloud.

3) Visualization of the results embedded into point clouds

To visualize the results embedded into point clouds you have two ways:

1. for each point of the point cloud, a results value (or more) is associated and, therefore, it could be used as a huge georeferenced dataset. The point cloud can be read as a table where each result value as a x,y and z coordinate.
2. import/open the poincloud in Cloud Compare (software open source available at https://www.danielgm.net/cc/);
3. when the importer-window appears define the first tree column as X, Y and Z coordinates, if RGB color is present, define column 4, 5 and 6 as R, G and B, and then all the other as 'Scalar field', and then confirm the import-option and import the pointcloud;
4. select the pointcloud in the DB tree panel, then, in the Properties panel define 'Scalar field' as color and then play with the histogram in the Scalar Field subsection to adjust the color scale.

3) System requirements

The system requirements are those defined by the MATLAB software. The app exploits the **parfor** function of MATLAB that works only with the Parallel Computing Toolbox suite of MATLAB 2008a or newer versions. Also the Computer Vision Toolbox suite is required. The app is fully tested on:

- high-performance workstations (Intel Xeon Gold 5218 and 64+ GB RAM) based on WINDOWS 10 operative system;
- a laptop MacBook Pro mid-2012 (Intel i5 dual-core 2.5GHz, 8GB RAM) based on OS X 10.13 (and newer version) operative system.

The minimum system requirements of MATLAB 2008a software expressed by Mathworks are available at:
https://www.mathworks.com/content/dam/mathworks/mathworks-dot-com/support/sysreq/files/SystemRequirements-Release2008a_Windows.pdf

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