

# FastDVC Simple Tutorials<sup>[1]</sup>

## 一、Base Theory

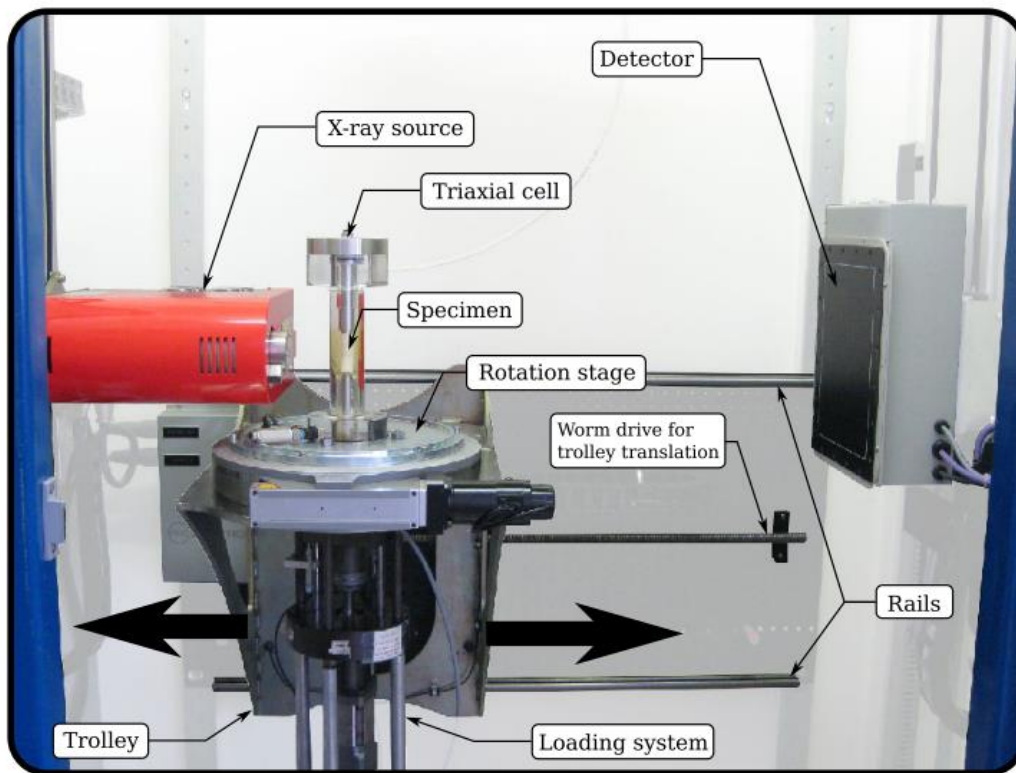
Based on the principle of digital image correlation, for details, please refer to the paper<sup>[2,3]</sup> and related papers involved.

And related papers involved:

$$\varepsilon_z = \frac{\sqrt{2}}{3} \times \sqrt{(\varepsilon_x - \varepsilon_y)^2 + (\varepsilon_y - \varepsilon_z)^2 + (\varepsilon_z - \varepsilon_x)^2 + \frac{3}{2}(\gamma_{xy}^2 + \gamma_{yz}^2 + \gamma_{zx}^2)} \quad (6.1)$$

$$\varepsilon_v = \varepsilon_1 + \varepsilon_1 + \varepsilon_1 = \varepsilon_x + \varepsilon_y + \varepsilon_z \dots \dots \dots (6.2)$$

式中， $\varepsilon_x$ 、 $\varepsilon_y$ 、 $\varepsilon_z$ 、 $\varepsilon_{xy}$ 、 $\varepsilon_{yz}$ 、 $\varepsilon_{zx}$ 分别为x、y、z方向的应变和剪应变。



**Fig. 3** Labelled photograph of the Laboratoire 3SR X-ray scanner, with background faded out for clarity

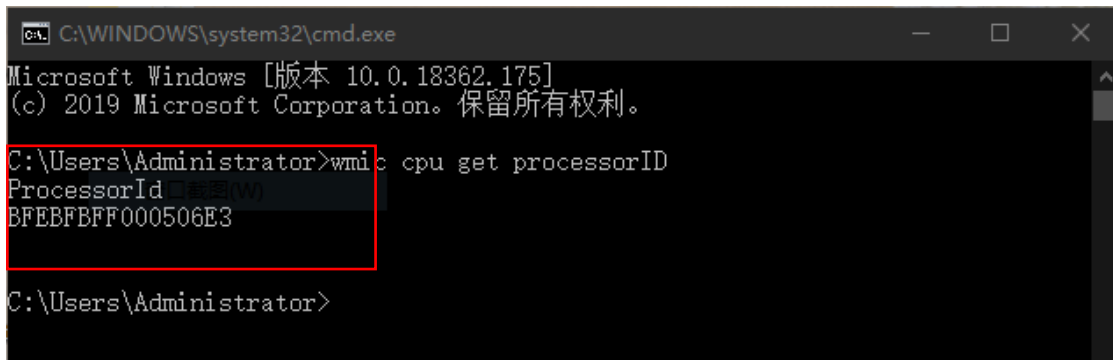
## 二、 User Manual

### 1、 How do I get it?

FastDVC download link (Zenodo): <http://doi.org/10.5281/zenodo.3610829>

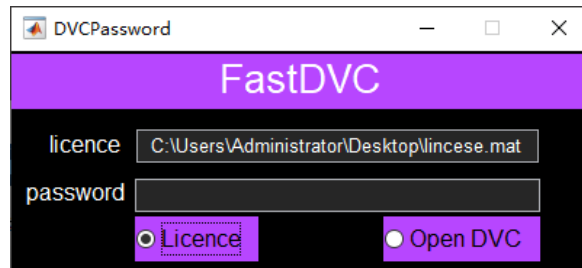
Open the software requires a unique key, a computer generates a unique key, you need to provide the installation software: host name and CPU ID.

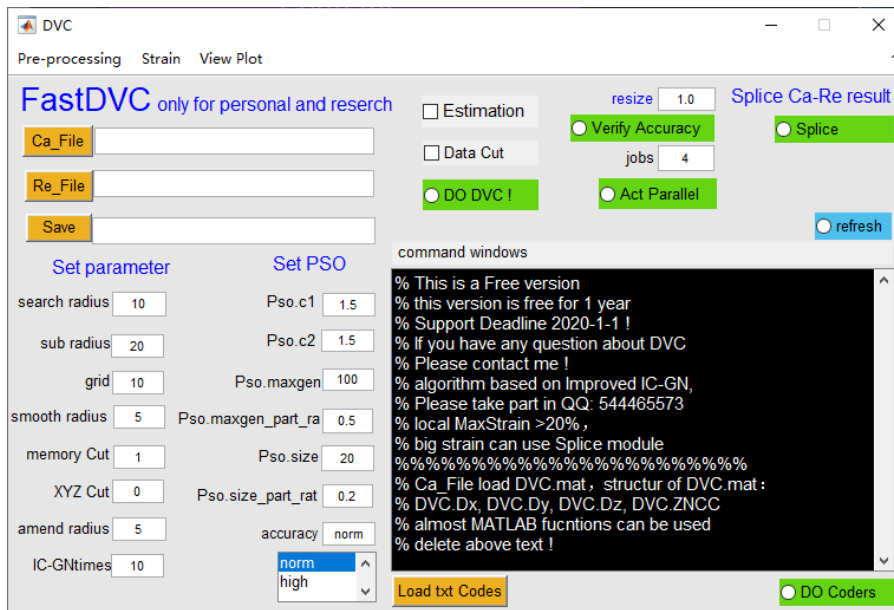
As shown below: In the cmd or shell, type: "**wmic cpu get processorID**" to get the relevant hardware information.



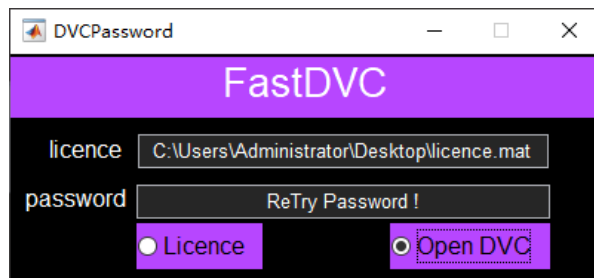
Generate a unique key, for example:

**1c9c8eeab2eced71a0600acce2b6ab0dcf1e8787d29d701d0f804cdb8xxx**, Open Licene path to open it.



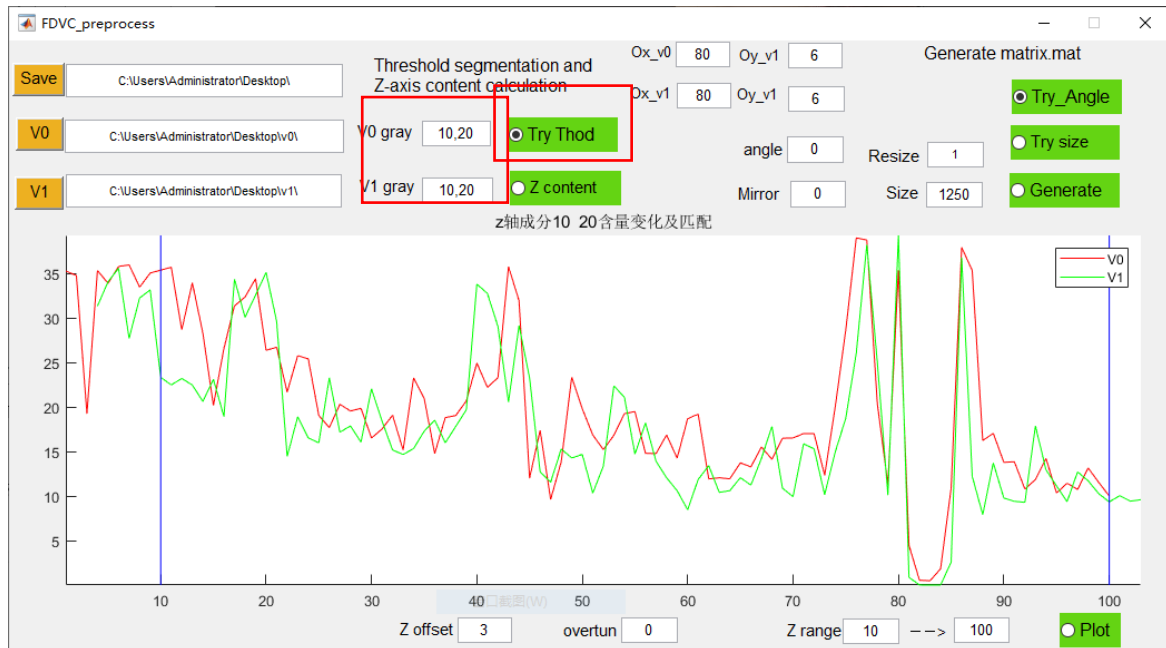


If the password is wrong then maybe like those:



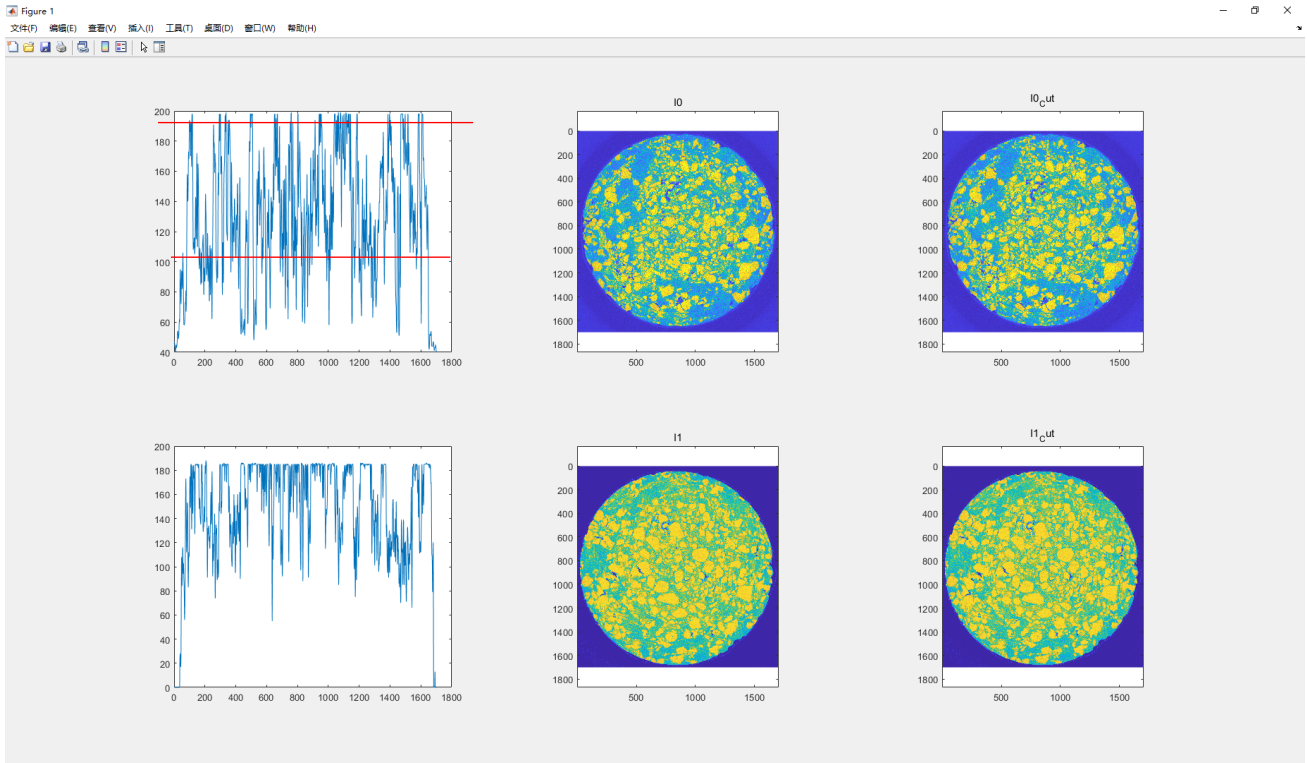
## 2、DVC Pre-processing

### 2.1 Segmentation threshold selection

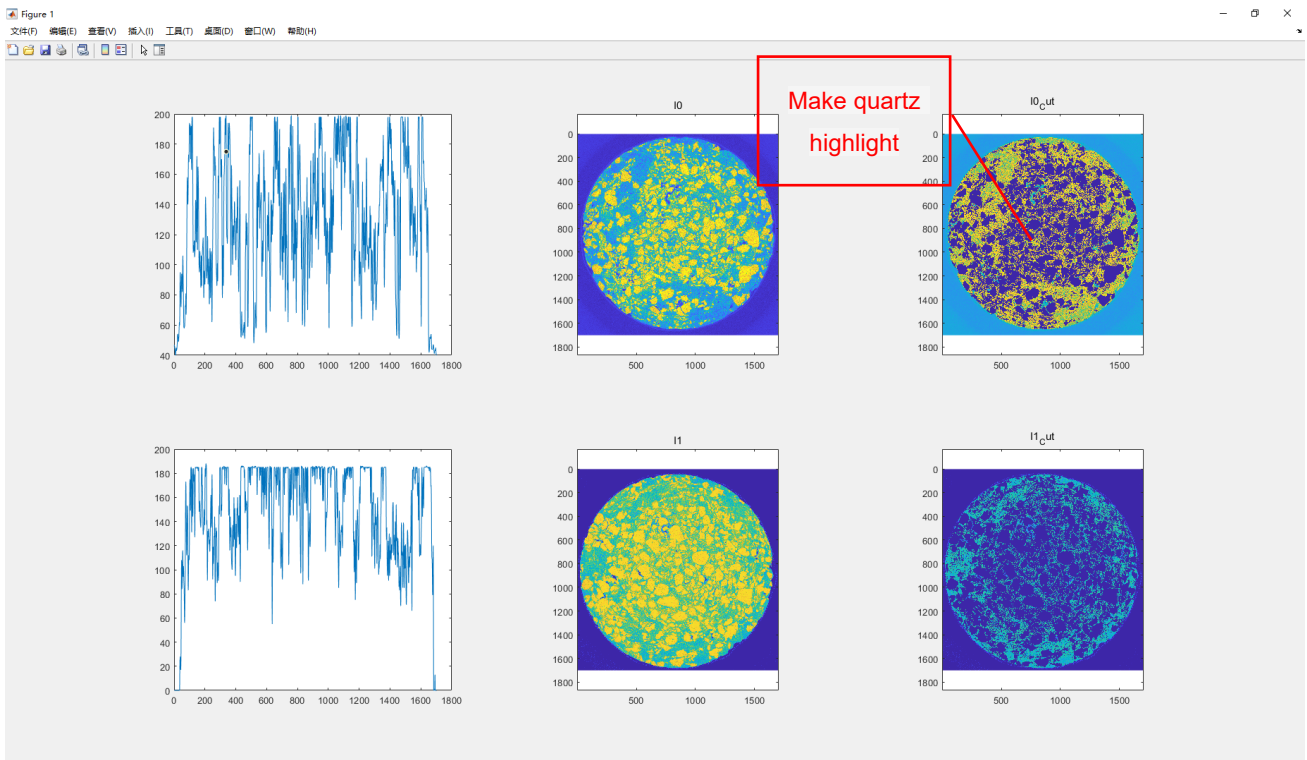


Chose the save path use **[Save]**、 Reference images **[V0]** and Current images **[V1]** file path (note: Currently only supports .tif format images, non-RGB3 layer data, preferably uint8 format, reducing memory requirements in big data ). The threshold is selected to adjust the matching of the two CT data on Z, reducing the post-DVC calculation pressure and improving the accuracy.

You can choose the segmentation threshold at the beginning, such as "0,1" (only this form, two values + one comma in the middle, and must be in English), enter **[Try Thod]** , Choose the appropriate threshold based on the most prominent and stable material in the results. As shown in the figure below, this material is a mixed soil containing clay and quartz particles, while quartz particles are relatively stable.

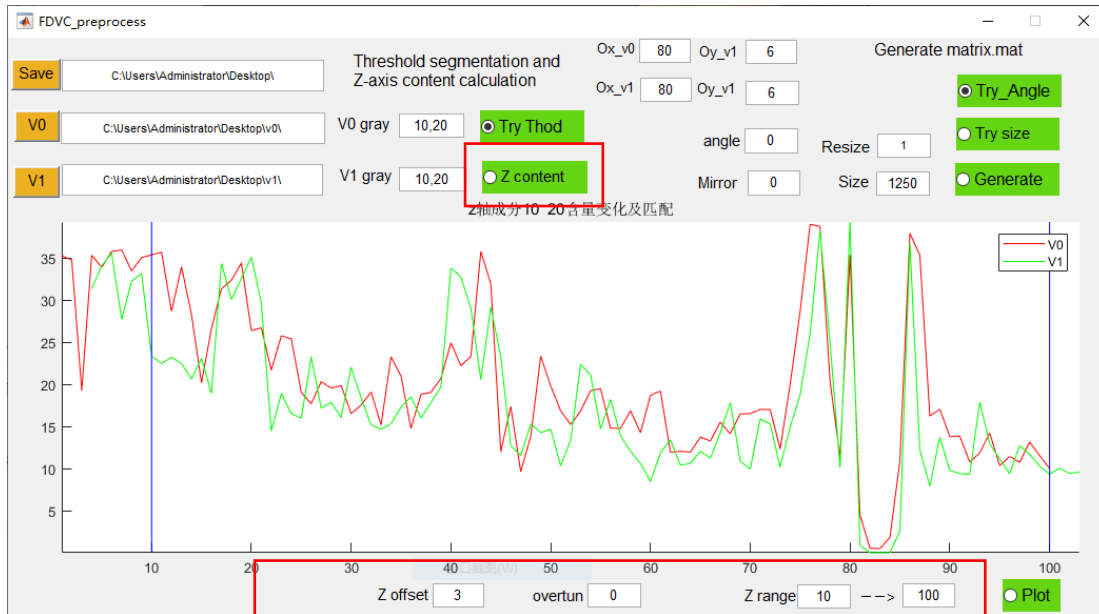


According to the cross-sectional view of the above figure, it can be confirmed that the approximate gray value range of the quartz particles (not very accurate) is “120,200”, and the following figure is obtained. The threshold range is continuously adjusted according to the comparison effect of Fig. subplot(2,3,2-3) and Fig. subplot(2,3, 5-6) until it is reasonable. until.



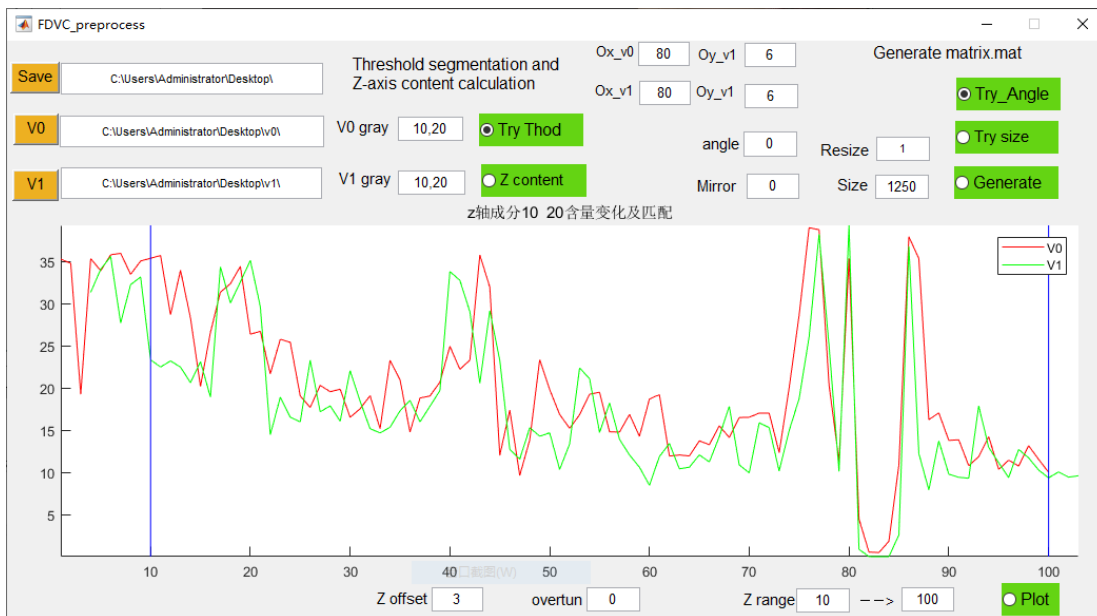
## 2.2 Z-axis content component matching and selection

When the threshold is selected OK, enter **[Z content]** Calculate the Z,axis content distribution of the selected threshold, and will generate **content.mat** and **Z.mat**。 Then enter **[Plot]** to plot curve about distribution of the content. If the sample is reversed during the CT scan, you must in the **[overtun]** input “1” ( Synchronous real-time loading generally does not occur in this situation ).



Change the value **[Z offset]** to match the two curves as much as possible.

Input the values **[Z range]** to select the range of layers you need to calculate. If you want to calculate most range of the sample, you may input big value, just like bellow Fig.



## 2.3 XY Angle

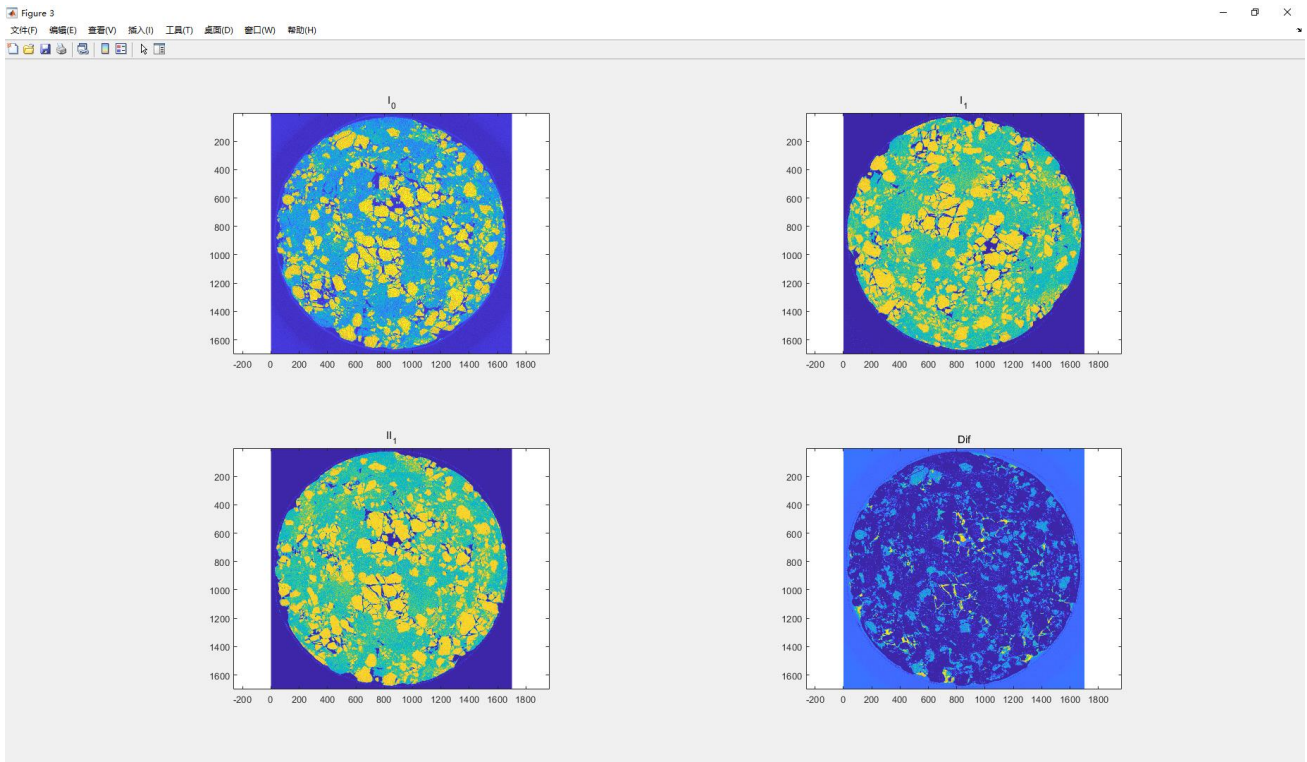
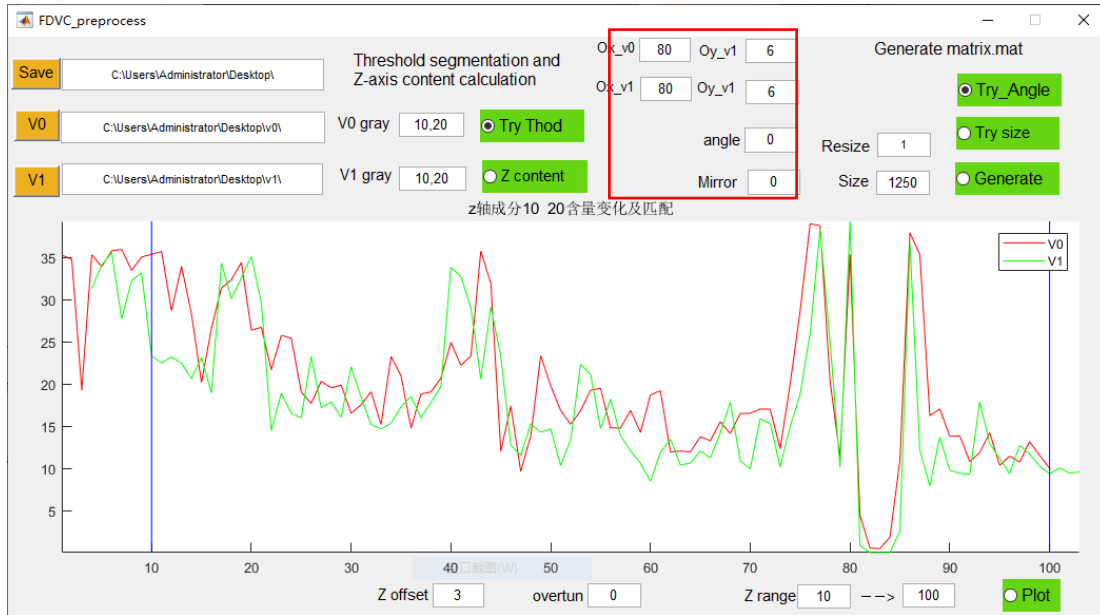
Also to reduce the calculation error, angle matching (Note: If it is real-time synchronous loading, set to 0, but you must click **[Try\_Angle]** (0-360°) to generate the corresponding setting parameters). If the sample is reversed during the CT scan, you must in the **[Mirror]** (0 not-overtun, 1 overtun) input “1”. Get reasonable angle matching by constantly comparing results. As shown below:

Note:

1) If the original CT picture is not centered, use [Ox, Oy] to adjust

2) If the size of the before and after tif images is different, you need to adjust [Size]

You can directly adjust the center offset parameter and the Size parameter by clicking [Try size]



## 2.4 Generate matrix.mat

The matrix can be generated when all the previous parameters are reasonable. But need to pay attention to:

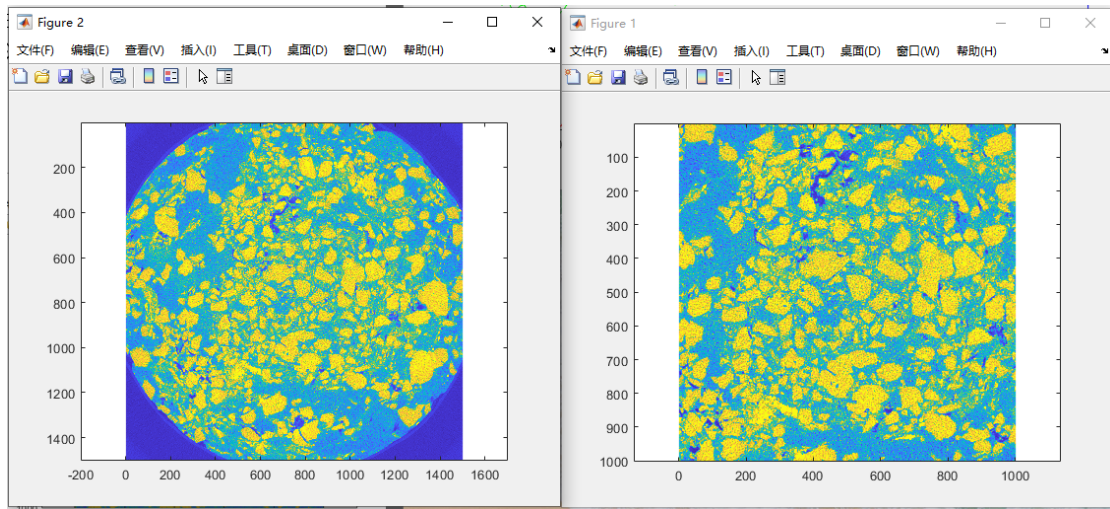
1) If the CT matrix is large (compared to the computer's memory), you can choose the right one. [resize], like "0.5", the initially 1000^3 change to 500^3;

2) If the calculated area is small, you can choose [Size] value to cut matrix data, and you can enter [Try



size] value to determine the best value。

When all the parameters are OK, then enter **[Generate]** to generate Date 'V0.mat' and "V1.mat"。



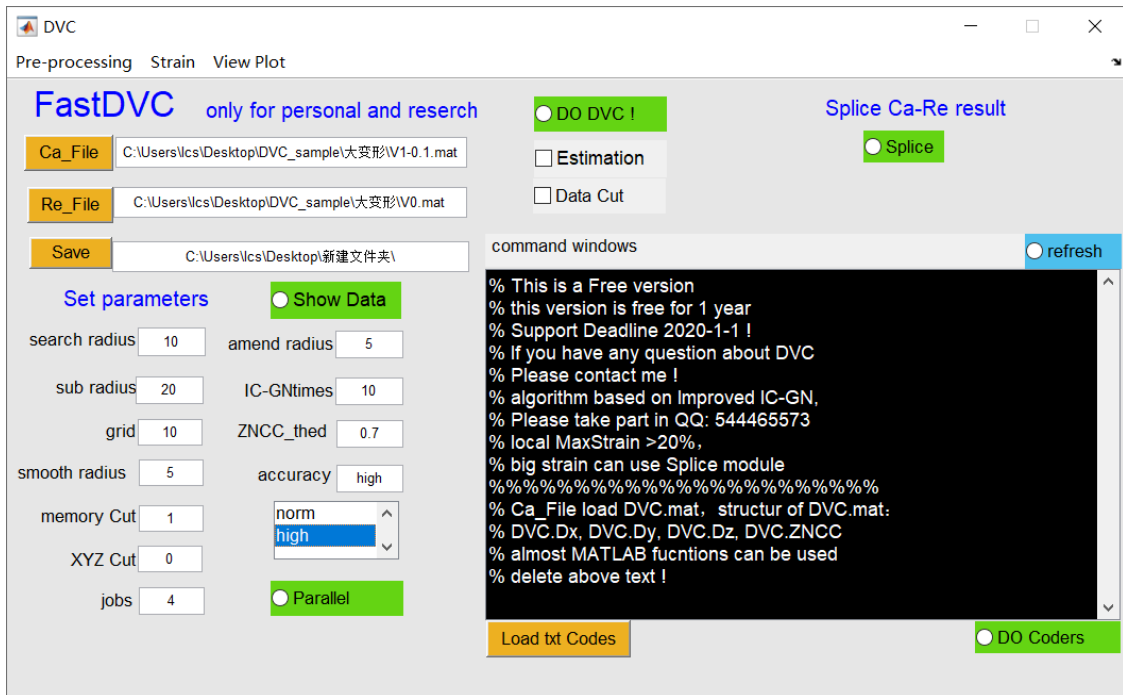


### 3 DVC Calculation

#### 3.1 Setting Parameters

Set **Ca File** and **Re File** (Open Data V0.mat and V1.mat) and **Save** path.

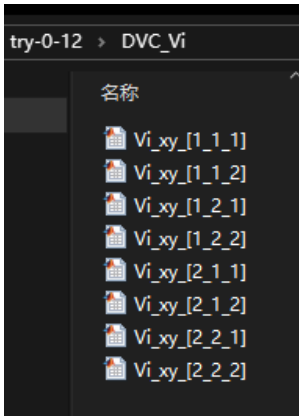
- 1) **search radius** Unit is a voxel, Search windows is  $(2*s+1)^2$ . Adjust the appropriate value with the **Estimation** module, which is generally slightly larger;
- 2) **sub radius** Unit is a voxel, Sub windows is  $(2*M+1)^2$ , small strain big M, big strain small M;
- 3) **grid** Calculation interval;
- 4) **smooth radius** It is the Gaussian filter radius. Generally, some noise will appear in the CT scan, and it will be preprocessed. If it has been processed, you can select a smaller value;
- 5) **memory Cut** Used to reduce the memory requirement operation. When the data is large (for example, greater than  $500^3$ ), you can select "3". When the data is small, you can select "1". Generally, you can select "2";
- 6) **XYZ Cut** It can be used when the calculation memory is small but the calculation data is large. For example, select "2" for  $2^3=8$  division;
- 7) **amend radius** useless;
- 8) **IC-GN time** Set the maximum number of algorithm iterations, the default is "10";
- 9) **ZNCC\_thed** if the  $zncc < ZNCC\_thed$ , those points need to be revised;
- 10) **accuracy** Current support: normal accuracy "norm" and high precision "high";



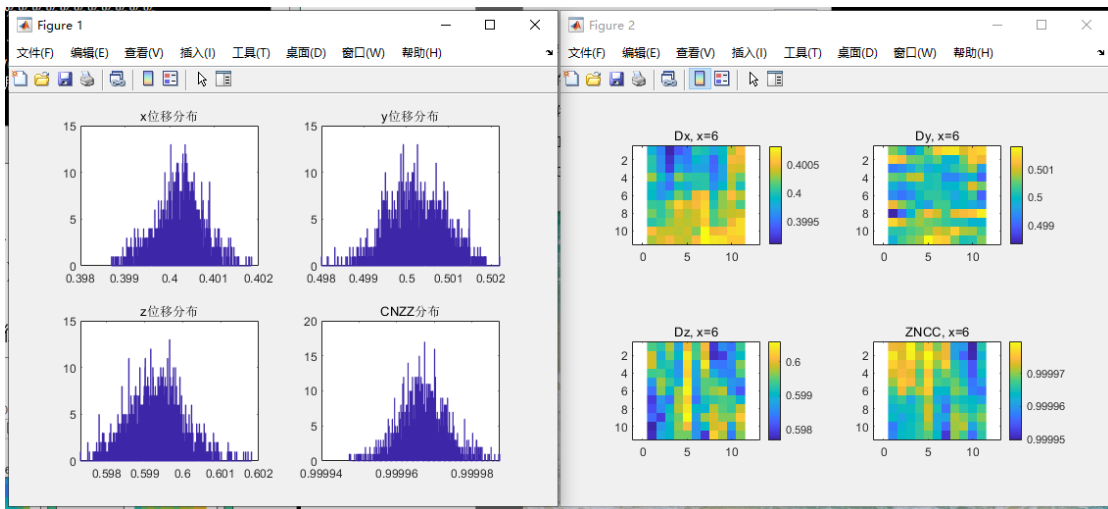
#### 3.2 DVC Calculation

Note: When performing calculations, be sure to select **Parallel** first, according to the number of cores of your own CPU, otherwise it will start too many cores and take up unnecessary memory (sorry: this bug is not solved yet). Turn off parallel calculation when the **jobs** value is "0-1".

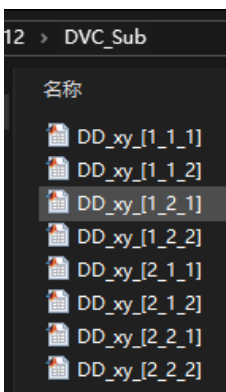
- 1) **Data Cut** : If you input **XYZ Cut** like "2", then enter **DO DVC !** and it will generate those data like :



2) **[Estimation]** : At the before of main DVC calculation, you need to adjust the **[search radius]** value to estimate the search radius by the Fig results.



3) When those parameters are all setting OK, **[Estimation]** and **[Data Cut]** both be cancel, and enter **[DO DVC!]** . There will show the important messages in **[command window]** during calculating process. As a result there will generate DVC.mat, if the **[Data Cut]** is not 1 or 0, there will generate DVC\_sub Data just like:



- 4) **[jobs]** : The best value is CPU cores;
- 5) **[Splice]** : It is a little complex, it will be introduced in the future.

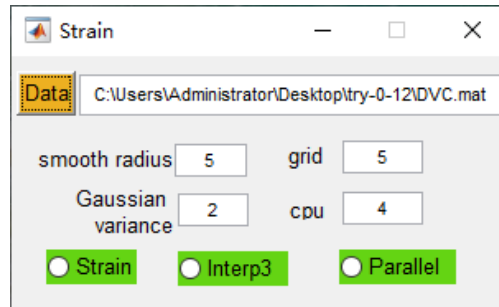
### 3.3 Data Editing

If you need correction or other operations on the calculation results, you can use the secondary editing function, which can execute most of the MATLAB's own functions and your own code, but you need to pay attention to the fact that the "%" symbol cannot appear in the code. Not solved yet).

1) If there is a well-written module code that can be saved as a TXT document (only TXT is supported), you can enter **【load txt code】** to load your code, then you can modify in **【command window】** ;

2) Before you enter **【Do codes】**, you must enter **【Ca\_File】** to load DVC.mat. Because the default is to edit the calculation result DVC.mat data, the struct of DVC.mat are: DVC.Dx, DVC.Dy, DVC.Dz, DVC.ZNCC。

## 4. Strain



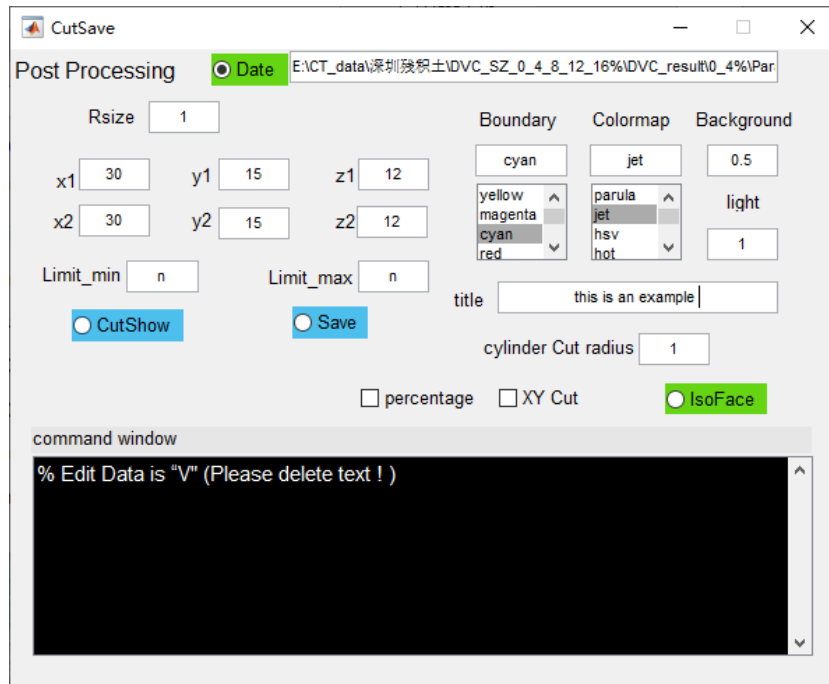
The strain method base on paper<sup>[5]</sup>.

- 1) **[Data]** : Choose the result data DVC.mat;
- 2) **[grid]** : The grid must be same with DVC's grid, otherwise it wrong !
- 3) **[smooth radius]** : General, you can choose is "5" or "10";
- 3) **[Gaussian variance]** : General, you can choose is "1-3";
- 4) When all the parameters setting OK, enter **[Strain]** then will generate data:

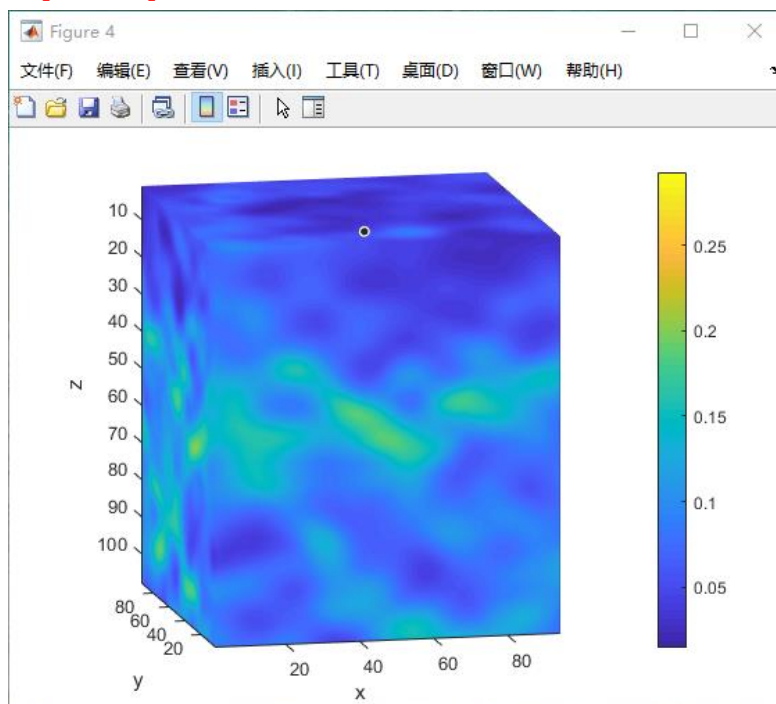
Data	explain
*_*_para	Least Squares Method for Solving Fitting Parameters
DVC_Dx/Dy/Dz	Displacement field in x, y, and z directions before smoothing
DVC_R_D1/D2/D3	stress $\sigma_1, \sigma_2, \sigma_3,$
DVC_R_Dts	Total displacement field $t_s = \sqrt{Dx.^2+Dy.^2+Dz.^2}$
DVC_R_Ds	Equivalent strain
DVC_R_Dv	Body strain $\sigma_v$
DVC_R_Dx/Dy/Dz	Smoothed displacement field of x,y,z direction
DVC_R_Dxx/Dyy/Dzz	Strain field in the x, y, z direction $\sigma_x, \sigma_y, \sigma_z$
DVC_R_Dxy/Dyz/Dzx	Shear field strain $\sigma_{xy}, \sigma_{yz}, \sigma_{zx}$

- 6) If you need to interpolate the strain result to the original matrix size, you can select the **[Interp3]** function, but at this time **[Data]** must select a result of the current **[Strain]** . If the data is large, the memory is tight.

## 5. View Plot: Post Processing



1) Choose the Strain result data, just like Ds.mat. Cut values x1, x2, y1, y2, z1, z2, you can enter **[CutShow]** then to see the figure to adjust the best values. At the same time, it can generate the Cut result data like Ds\_Cut.mat, this data can be used to **[Iso Face]** .

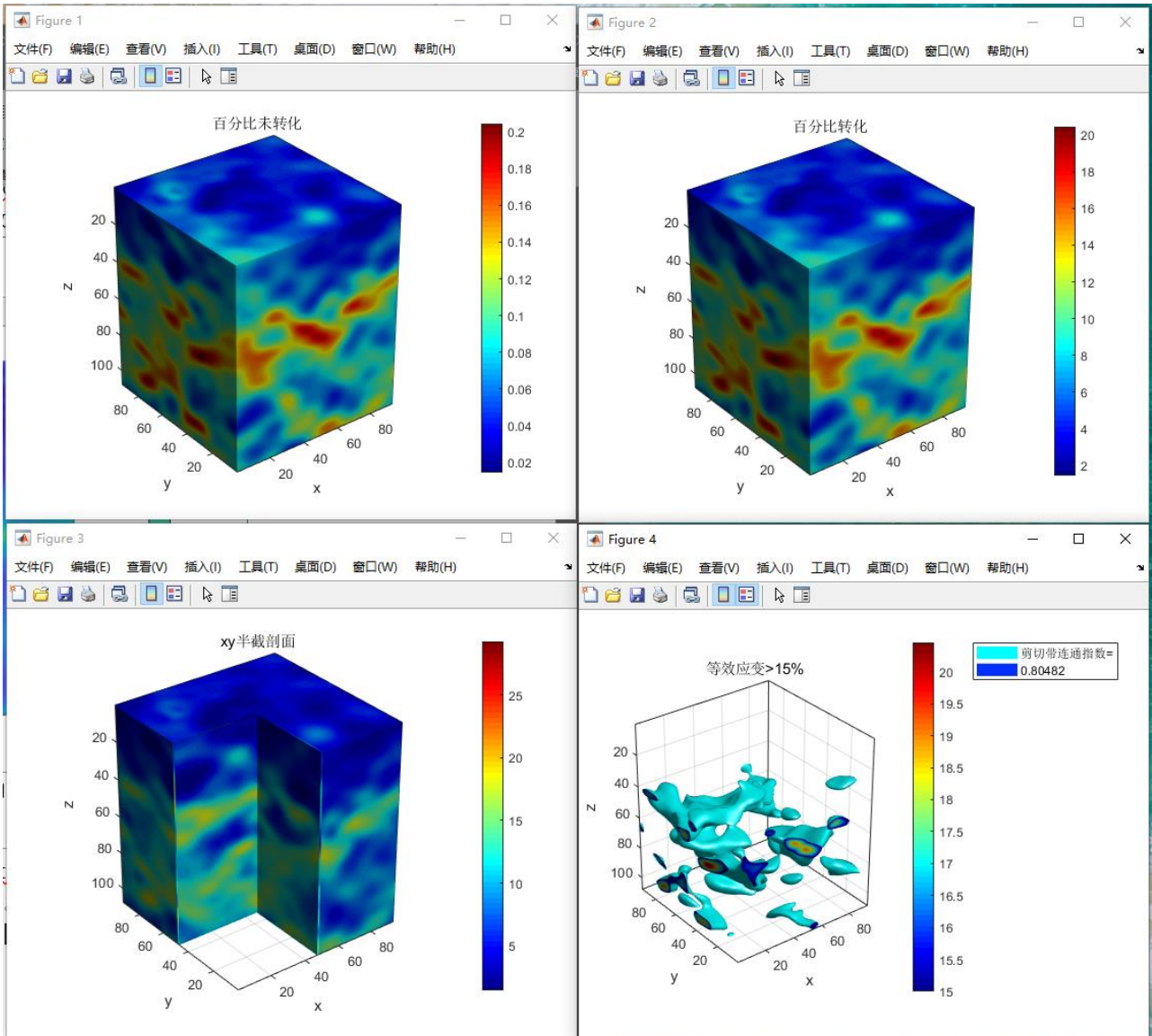


The **[Limt\_min]** and **[Limt\_max]** can choose the show range, If you enter string(like “n”), it will be show all range value.

2) **[Save]** can save the **[Cut Show]** data to tif image, those images can be edit or show by other software, like Avizo.

3) **[IsoFace]** : You can set **[Boundary]**、**[colormap]**、**[Background]** and **[light]** to show volume data,and

the **[title]** add the title of fig.  
**[percentage]**、**[XY Cut]**;



In the process of calculating the shear band, the connectivity index of the shear band can be calculated simultaneously. (The connectivity index is in the range [0,1]. When the shear band is completely connected, the connectivity index is 1, and when the ideal is completely discretely isolated, it is close to 0).

If you need to edit the volume data, you can directly perform data operation in the **[Command Window]**. The operable data is "V", and the format is the same as the **[DVC]** module.

## 参考文献:

- [1] Li C, Shu R. Accurate and simple digital volume correlation using pre-interpolation. <http://doi.org/10.5281/zenodo.3600641>: Zenodo, 2020.
- [2] 潘兵, 王博. 数字体图像相关方法研究进展[J]. 科学通报, 2017, (16):1671-1681.
- [3] 苏勇, 张青川, 伍小平. 数字图像相关技术的一些进展[J]. 中国科学:物理学 力学 天文学, 2018, v.48(09):29-53.
- [4] Alikarami R, Andò E, Gkiouas-Kapnisis M, et al. Strain localisation and grain breakage in sand under shearing at high mean stress: insights from in situ X-ray tomography[J]. Acta Geotechnica, 2014, 10(1):15-30.
- [5] 潘兵, 谢惠民. 数字图像相关中基于位移场局部最小二乘拟合的全场应变测量[J]. 光学学报, 2007, 27(11):1980-1986.