SCIAN-Drop & SCIAN-Force Usage Instructions

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The software was tested in Windows 11 with a 12th Gen Intel(R) Core(TM) i5-1240P of 1.70 GHz, 8 GB of RAM DDR4 without a dedicated graphics card. Thank you for using the software.

SCIAN-Drop

For a droplet inmmersed in a given medium, the interfacial tension γ can be obtained from the equation:

$$\gamma = \frac{\Delta\rho g Ro^2}{Bo}$$

$\Delta\rho$ is the mass density difference between the drop and the medium, g is the gravitational acceleration, Ro is the radius of curvature at the drop apex and Bo is the Bond number [1]. For more information, see the SCIAN-Drop documentation and source code in the repository [2]. Its implementation was done entirely in Python, using different libraries detailed in the same site. Please, provide the required input paramaters and image in the order shown below to avoid mistakes.

1. Input Parameters

First, in the **"Parameters"** panel enter the image-independent parameters:

- droplet density, in $[Kg/m^3]$
- medium density, in $[Kg/m^3]$
- needle width/thickness, in gauge units

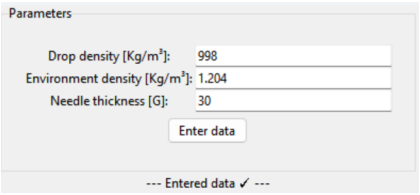


Figure 1: Example of first input data.

Once you entered de values, press the button *Enter data*. After visualizing the message *Entered data*, you can proceed to the next section. For example, under (approximately) normal conditions, a drop of water (density of 998 $[Kg/m^3]$) in air (density 1.204 $[Kg/m^3]$), hanging from a 30-gauge needle, should correspond to the parameter values shown in Figure 1.

2. Input Image

Next, select the image in the **"Image"** panel of the software. You can select a binary image that has been segmented already, or rely on the software basic segmentation functions. Check *Binary image* in the first case. As example, a binary image of a droplet whose Bond number is 0.21 is available in the "bonds" folder. When loaded, it should appear as shown in Figure 2.

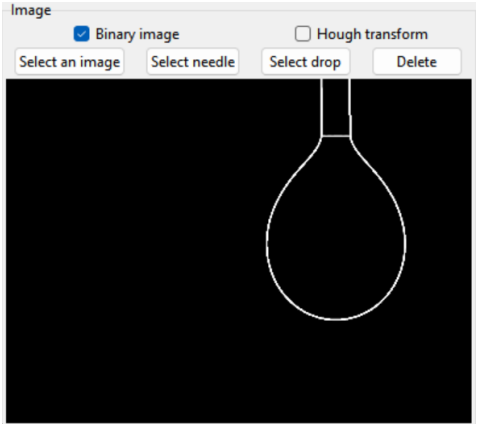


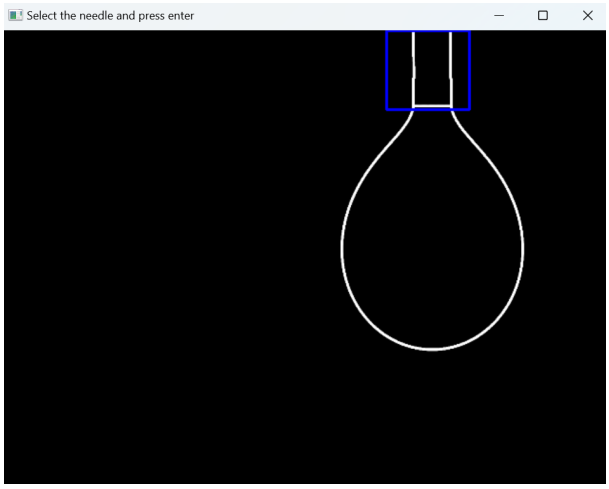
Figure 2: Visualization after loading the example binary image.

Next, define bounding rectangles for the needle and the drop, by using the respective buttons. The selection window should look like Figure 3a. Using the mouse, choose the region of interest from one end of the rectangle to the opposite end, and press `Enter`.

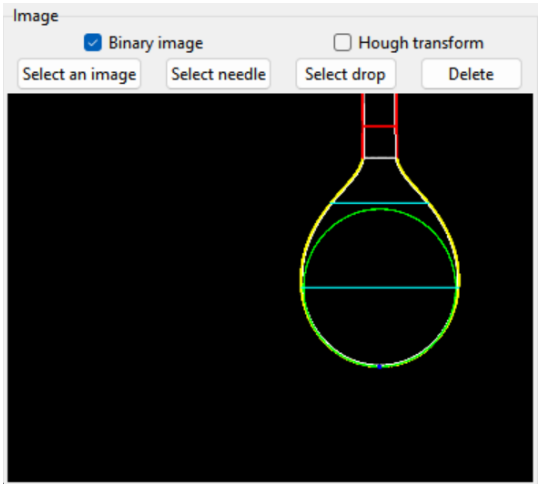
In order to calculate the droplet descriptors, the program fits a circle onto the droplet contour. Two fitting methods are available for both binary and non-binary images:

- The default method fits the larger circle which passes through the *apex* and is contained in the droplet.
- The alternate method uses the Hough transform to fit the circle [3]. It has a higher computational load (but it does not necessarily yield a better estimation).

Once both areas are defined, the **"Image"** panel should look like Figure 3b. In case of any correction, you can press *Delete* and make the selections again.



(a) Window for needle selection (bounding rectangle).



(b) Display of the selections for the example binary image.

Figure 3: Window for selection and display of the image.

3. Output

If the input sections were filled correctly, at the top of the **"Results"** panel, a message will be displayed with the button *Calculate* enabled (Figure 4). Once you press this button, you will get the measured droplet descriptor values:

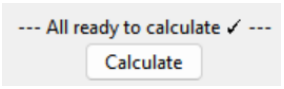


Figure 4: Message indicating that you can perform the calculations.

- radius (`Ro`)
- Bond number (`Bo`)
- ratio $^{Ds}/_{De}$ (σ)
- interfacial tension (γ)
- Worthington number (`Wo`)
- Neumann number (`Ne`)
- droplet volume (`V`)

For more information about you can visit the repository [2]. If you want perform a new calculation, press the button *New calculation*. An example of the final result is shown in Figure 5.

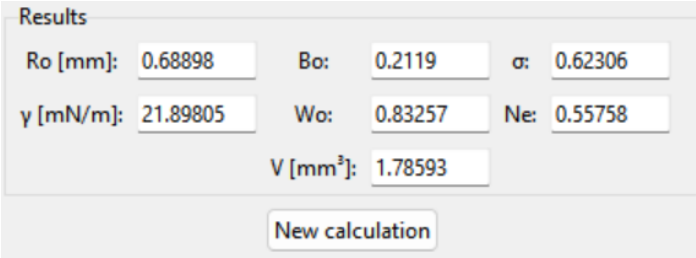


Figure 5: Final results of the procedure for the example image.

SCIAN-Force

The anisotropic component of the normal stress in a droplet is given by:

$$\delta\sigma_{nn}(q) = 2\gamma\left(H(q) - \frac{1}{R}\right)$$

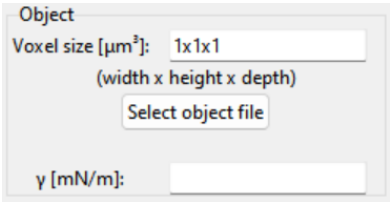
$H(q)$ represents the mean curvature at point q, γ denotes the interfacial tension of the droplet and R is its original radius [4]. To use the software, fill in the input data in the order presented below to avoid mistakes. The visualization of the stress is dynamic and interactive. Its implementation was done entirely in Python, using several libraries, which are detailed in the repository [2].

1. Input Object

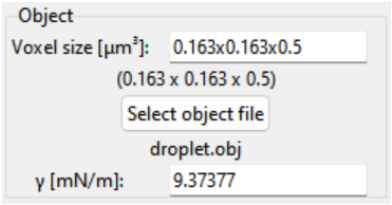
First, complete the section **"Object"** (see Figure 6a) which provides the input data for the surface droplet model, in a 3D "object" file format. Here, you can choose the object to be processed by pressing the button *Select object file*. Supported object formats for include `.OFF` and `.OBJ`. It is possible that the size of the object (voxel size) does not match the real dimensions; therefore, you can modify this parameter through *Voxel size*. Here, you can input the actual size that the voxel should have. The required format syntax is `'width x height x depth'`, which can also be seen as the length in the `x`, `y` and `z` axes, respectively.

For example, a fluorescence microscope was used to obtain z-axis slices of a droplet (droplet.obj in the samples folder), with a voxel size of `0.163 μm x 0.163 μm x 0.5 μm`. With this, a 3D reconstruction was obtained, whose unit of measurement is in voxels, saved in a file `'droplet.obj'`. With this in mind, if the scale of the drop does not match the real one, the voxel size must be entered as a parameter and then the file must be selected. Verify that everything has been loaded correctly by looking at the displayed the voxel size label under the button, in parentheses.

The value of the droplet *interfacial tension* γ is required to calculate the pressures. Therefore, you must type it in the corresponding box, in $[^{mN}/_{m}]$ units. The default value is 1. The result should appear as in Figure 6b.



(a) First look of the input fields and labels, before editing.



(b) User edited parameters are displayed in the labels below the input fields.

Figure 6: Filling the droplet object parameters in the "Object" panel.

2. Colorbar

In the **"Colorbar"** panel, you can set the maximum and minimum values in the input fields for the color scale to be applied to the surface model. If any of the fields are empty, the corresponding (maximum or minimum) value from the object's stress will be used. Having a fixed scale can be useful for comparing two objects with different pressure values. For example, if you set `1` y `-1` as the maximum and minimum value respectively, the color bar should look as in Figure 7. If the parameters in this section will be customized, you must do it before using one of the methods in the next section. If you enter a range that does not cover all of the possible data values, the graph may be properly rendered. In general, warm tones indicate positive forces, cool tones represent negative forces, and white represents force with magnitude 0 (or close to it).

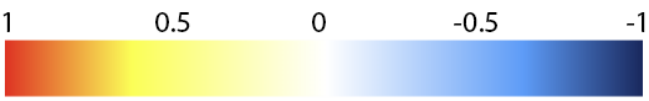


Figure 7: Color bar in a range of `[-1, 1]`.

3. Normal Stress and Surface Plots

After setting up the inputs, you must use some method from
"Plot" section to obtain the normal stresses of the object. For this, press any button of interest. Each method has a different effectiveness and computational cost, *Rusinkiewicz Method* is recommended based on the algorithm of the library `trimesh2` in `C++` [5]. Once selected, a window should open in your default browser, displaying the graph of the object like the Figure 8. Depending on your computer, the window may show an error. This is normal, run the method again.

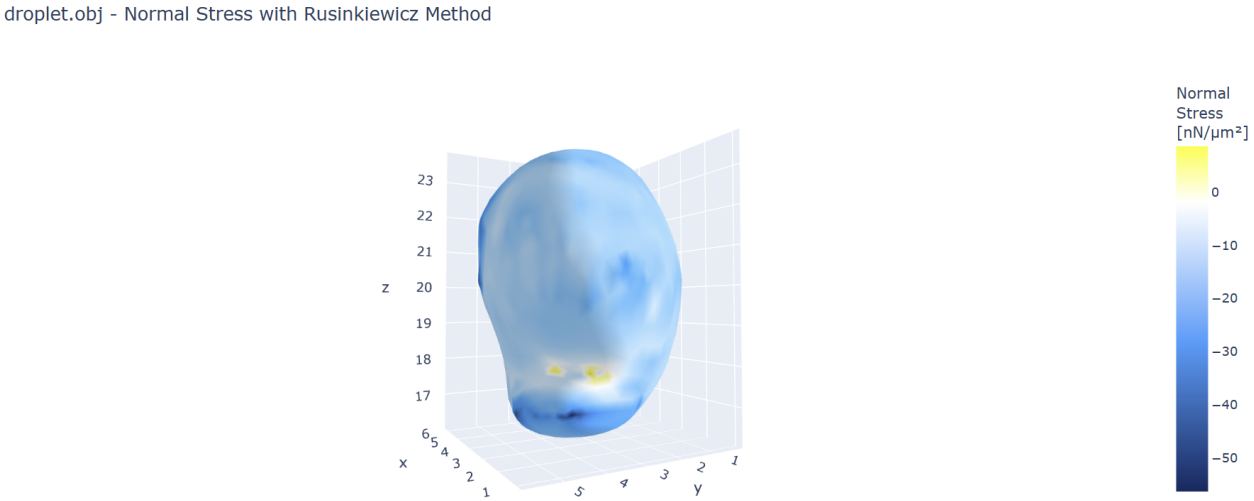
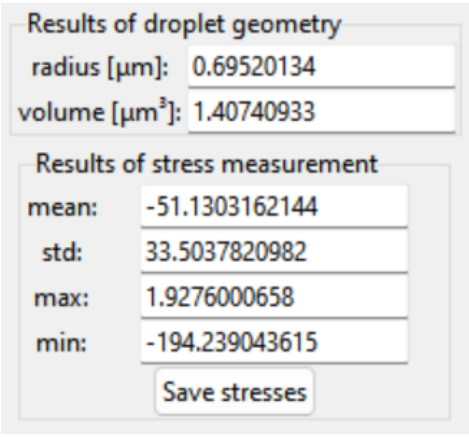


Figure 8: 3D graphic window of the object.

4. Output Results

After plotting the surface and stress, the results of the `average`, `maximum`, `minimum` and the `standard deviation` of the normal stresses, will appear in the **"Results"** panel, together with the drop `volume` and original `radius`, which correspond to an ideal sphere of the same volume. Also, the results of the normal stresses at each surface vertex can be exported to an Excel spreadsheet in `.xlsx` format, by pressing the button *Save stresses*, and selecting the location where you want to save the data. For example, considering the same object as above, the results look like in the Figure 9.



(a) Results panel with the values of interest.

vertex	coord	normal_stress
0	(1.8640703, 2.617475, 16.908533)	-22.47105946
1	(1.7479194, 2.746778, 17.035107)	-23.08462353
2	(1.7438341, 2.5823011, 17.14509)	-19.68691565
3	(1.8291264, 2.8992753, 16.835342)	-23.10693137
4	(1.7270557, 2.9733243, 17.050777)	-23.25734719
5	(1.8108804, 3.18366, 16.823418)	-23.2178272
6	(1.7290708, 3.271485, 17.056515)	-25.10474834
7	(1.8066688, 3.4850159, 16.830359)	-24.10606336
8	(1.7436371, 3.5775812, 17.058414)	-27.82379019
9	(1.810666, 3.7818148, 16.851383)	-26.60221654
10	(1.7623566, 3.8659396, 17.061516)	-33.57207698
11	(1.8194844, 4.0515995, 16.889565)	-31.51174575
12	(1.7836096, 4.1135063, 17.067543)	-46.30311749
13	(1.8329189, 4.2679462, 16.946222)	-33.62308361
14	(1.8091619, 4.2842627, 17.07038)	-56.39122266
15	(1.8518584, 4.393956, 17.012455)	-42.81000985
16	(2.0170295, 2.330897, 16.96003)	-19.04372181
17	(1.8129697, 2.4319077, 17.129547)	-29.89049835

(b) Spreadsheet data with the measurements for each object vertex.

Figure 9: Final results of SCIAN-Force.

References

[1] Berry D. J. *et al.*, "Measurement of surface and interfacial tension using pendant drop tensiometry," *Elsevier Inc. Journal of Colloid and Interface Science*, 2015.

[2] M. Concha and S. Härtel, "SCIAN-Lab. Optics, Forces and Development Course 2024," Mar. 2024. [Online]. Available: https://scian.cl/scientific-image-analysis/optics-forces-and-development-course-2024/

[3] Open Source Computer Vision (OpenCV), "Hough circle transform," [Accessed: March, 2024]. [Online]. Available: https://docs.opencv.org/3.4/d4/d70/tutorial_hough_circle.html

[4] Campàs O. *et al.*, "Quantifying cell-generated mechanical forces within living embryonic tissues," *Nature America, Inc.*, 2014.

[5] S. Rusinkiewicz, "Estimating curvatures and their derivatives on triangle meshes," in *Symposium on 3D Data Processing, Visualization, and Transmission*, Sep. 2004.