OpenBOS

Software Manual

The Open-Source Background-Oriented Schlieren Imaging System

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1.0 Generating a Background

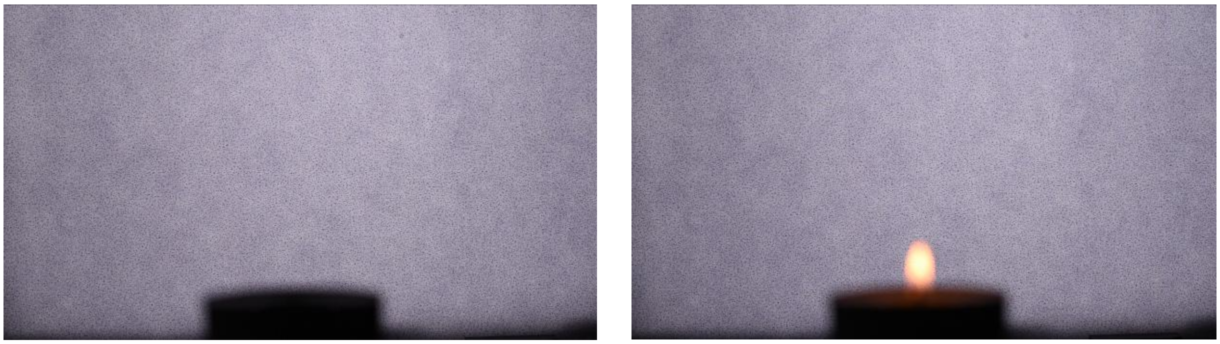
- Go to GitHub and download the "OpenBOS Software" zip file.
- Open the file "background.m"
- Once the program has loaded, update the Parameters section. The parameters are as follows:
  - **f**: The camera focal length, this is dependent on the lens being used. This value is given in millimetres but is represented in meters in the code, thus a conversion must be made.
  - **P**: The pixel pitch, this is a feature of the camera being used. This parameter can be found on the internet.
  - **ZB**: The distance between the background and the focal point. This is measured using the tickers on the apparatus in centimeters. The focal point is the focal length, f, subtracted from the position of the camera. The value is in meters in the code, so a conversion must be made.
    - *Sample calculation: The ticker on the camera sled is located at 119.5 cm, the focal length of the lens is 105 mm. Here, ZB=1.195-0.105, in meters.*
  - **Lx, Ly**: The size of the paper in the x and y directions, respectively, in meters.
  - **dot_size_pixels**: the size of the dots, in pixels
  - **dot_spacing**: the spacing of the dots
- Once all parameters have been updated, run the code. A copy of the background will automatically be saved as a .pdf file to the same directory as "background.m"

2.0 Recording a Video

- Ensure the position of the sleds have been adjusted and the camera settings have been configured according to the **Hardware Manual** and the parameters of your experiment.
- Record the video without the experiment for 2-5 seconds to obtain a **reference frame**, then while the video is still recording, start the experiment and record for 15-30 seconds.

  e.g. If the experiment is a candle, start recording while the candle is unlit as the **reference frame**, then light the candle and continue recording for

15-30 seconds. Figures 1a & b display screen clippings from the same video, with the reference frame on the left and the candle lit on the right.



Figures 1a & b: Reference frame and frames after candle is lit.

<u>Tip:</u> A longer video does not necessarily make for a better result. It is better for processing time to use as short a video as possible that includes the desired flow to study, but if the entire behaviour of the flow can be used if needed.

3.0 Using the OpenBOS Program

- Go to GitHub and download the "OpenBOS Software" zip file.
- Open the file "demo.m"
- Once the program has loaded, update the Parameters section. Some of the parameters, such as f, P, ZA, ZD, D, and Lref are dependent on the experimental setup, where n0, G, patm, and R are dependant on the medium, which is air in this case. There are two other parameters, windowsize and overlap. The overlap must be smaller than the window size, and as the overlap approaches the window size, the resolution gets higher. The parameters are as follows:
    - **f**: The camera focal length, this is dependent on the lens being used. This value is given in millimetres but is represented in meters in the code, thus a conversion must be made.
    - **P**: The pixel pitch, this is a feature of the camera being used. This parameter can be found on the internet.
    - **ZA**: The distance between the object and the focal point. This is measured using the tickers on the apparatus in centimeters. The focal point is the focal length, f, subtracted from the position of the camera. The object location is found using the ticker on the sled that holds the experimental object. The value is in meters in the code, so a conversion must be made.

Sample calculation: The ticker on the camera sled is located at 119.5 cm, the focal length of the lens is 105 mm, and the object is at 56 cm. Here, ZA=(1.195-0.105)-0.56, in meters.

- **ZD**: The object location relative to the background. This location is found by examining the ticker on the object sled. This value is measured in centimeters but must be converted to meters for the code input.
- **D**: The depth of the medium, displayed in Figure 2. This is the depth of the flow into the background from the perspective of the camera and can be found by measuring the object. The value in the code is in meters.

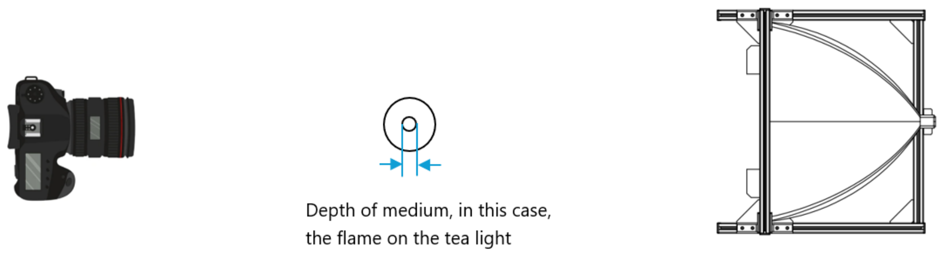


Figure 2: Diagram displaying depth of medium.

- **Lref**: The calibration reference length displayed in Figure 3. This is the width of the object observed by the camera and is used in a later processing step to give reference measurements to the software from the video.

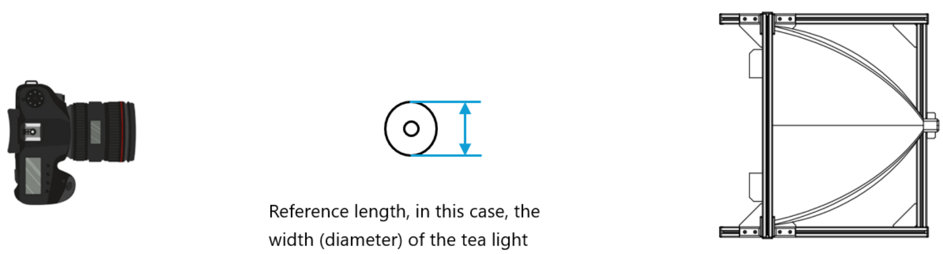


Figure 3: Diagram displaying reference length.

- **n0**: The index of refraction of the medium. This value is a scientific parameter that can be looked up online or in other relevant research materials
- **G**: The Gladstone-Dale constant of the medium, in m^3/kg.
- **patm**: The atmospheric pressure of the medium, in Pa.
- **R**: The specific gas constant for the medium, in J/kgK

- Import the video taken in Section 0 to the same directory as the program, displayed in Figure 4.

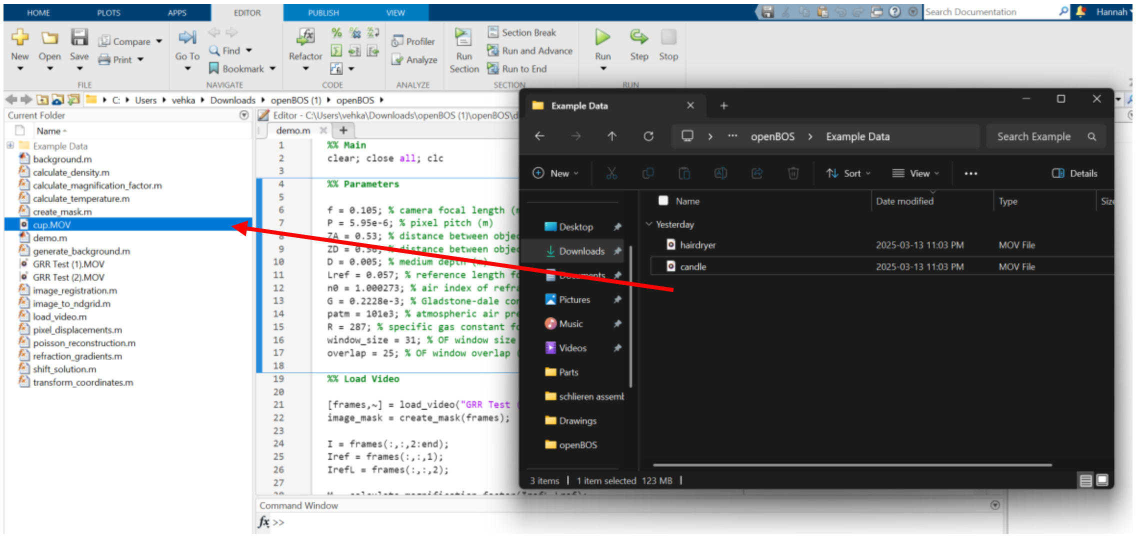


Figure 4: Import video into program directory.

- Update the code to match the name of the video on line 21, as in Figure 5.

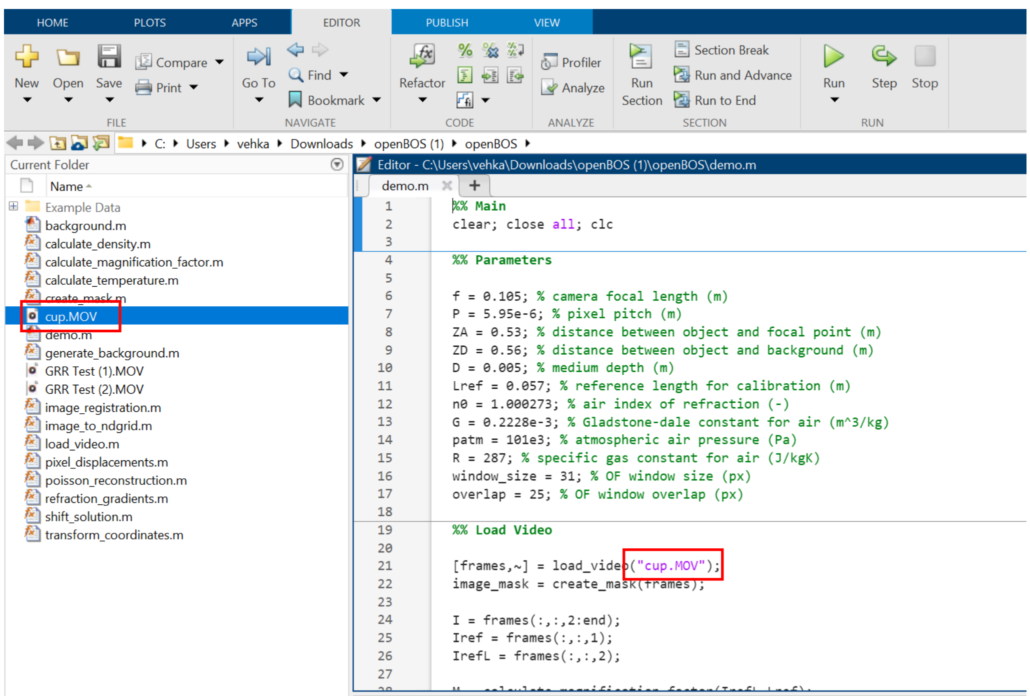


Figure 5: Update code with video name.

- Run the program.
- Crop the video frame to include the **area of study**, which is where the distortions of the flow will be observed, and potentially the experimental object as well. Crop

out the dark edges of the image and any objects aside from the experimental object, such as the bottom of the background frame. The **study area** is bound by the red box. The experimental object will me masked in the following steps so it will not interfere with the displacement vectors, and it will be useful to have the object to obtain the **reference length** later on. This is displayed in Figure 6.

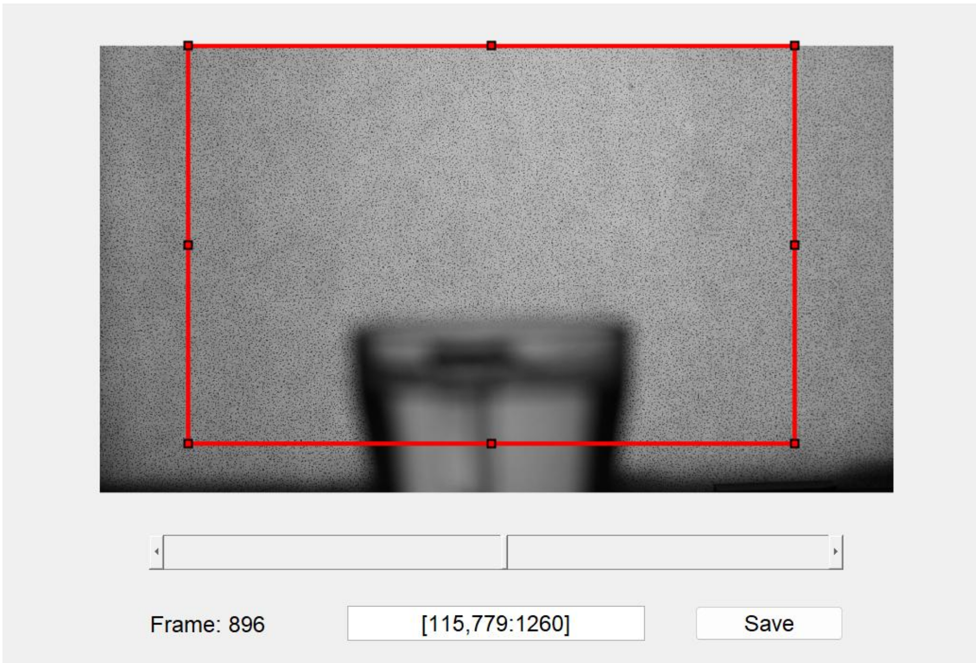


Figure 6: Video cropping.

- Select the frames to retrieve data from. Use the slider to scroll through frames from the video, shown in Figure 7.

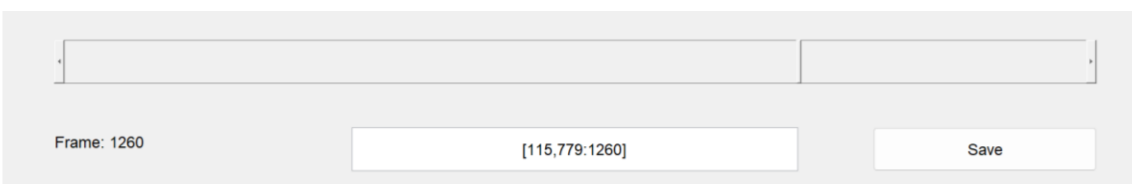


Figure 7: Frame selection slider.

The first frame in the selection will be the **reference frame**, one that serves as a blank reference to compare distortions against. This frame does not include the experiment, and frames 1-5 should not be used as the first slide. An example of a reference frame for hot mug is shown in Figure 8.

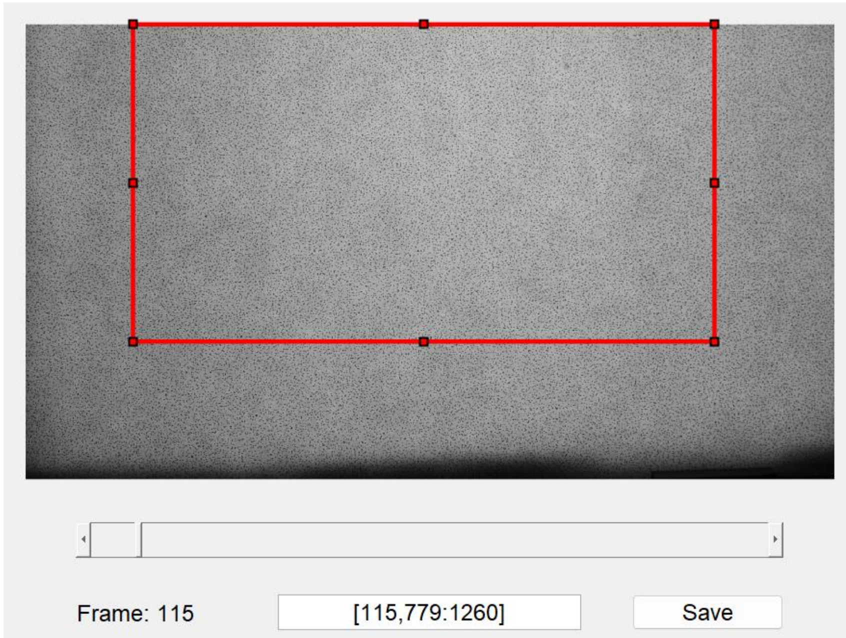


Figure 8: Reference frame for hot mug example.

Next, the range of **frames to study** will be selected. These frames should show the experiment and any flow conditions to be studied. Less frames allow for a faster processing time, so using a range of roughly 300 frames is suggested for fast results while using an appropriate amount of data. The frame selection uses MATLAB notation, where single frames are separated by commas and ranges of frames use colons. As shown in the example above, the reference frame is frame 115 and the range of frames to study is from 779 to 1260, shown as [115,779:1260].

- Once cropping and frame selection is complete, click "Save".
- Next, the experimental object must be **masked**. Find a frame where the object is visible and use the "Mask" button to start masking. Trace around the edge of the object and connect the line back to the starting point to create the shape. Scroll through the frames to make sure that anything moving has been masked, otherwise those movements will overpower the optical flow algorithm. The mask does not have to be the exact shape of the object, it can be a little larger, but not smaller than the object. Once the shape is formed, the points can be adjusted. Drag the bottom corners down to the bottom edge of the frame to make sure they are no disturbances in the processing stage. This is shown in Figure 9.

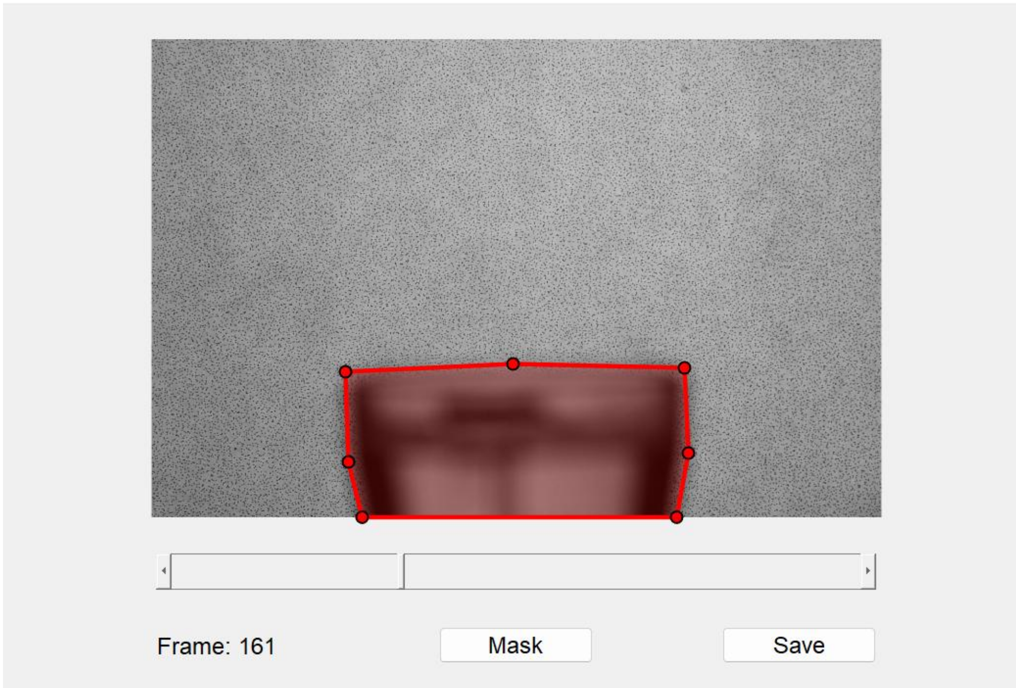


Figure 9: Masking for mug example.

- Once the masking is complete, click “Save”.
- Next, the **reference line** has to be drawn in the length calibration window, as displayed in Figure 10. This pop-up window is sensitive, so be careful to <u>click and hold</u> while drawing the reference line. The line should be drawn to match the width specified in the parameters above. The window will close as soon as the mouse is released.

Figure 10: Reference line for mug example.

- After the reference line is drawn, the images will start to process, and the plots will appear, as in Figure 11.
- The **plotting window** does not show the final result immediately, all of the images need to be processed. This process can be stopped at any time, if desired, by pausing the code. The final frame for this example is shown below.

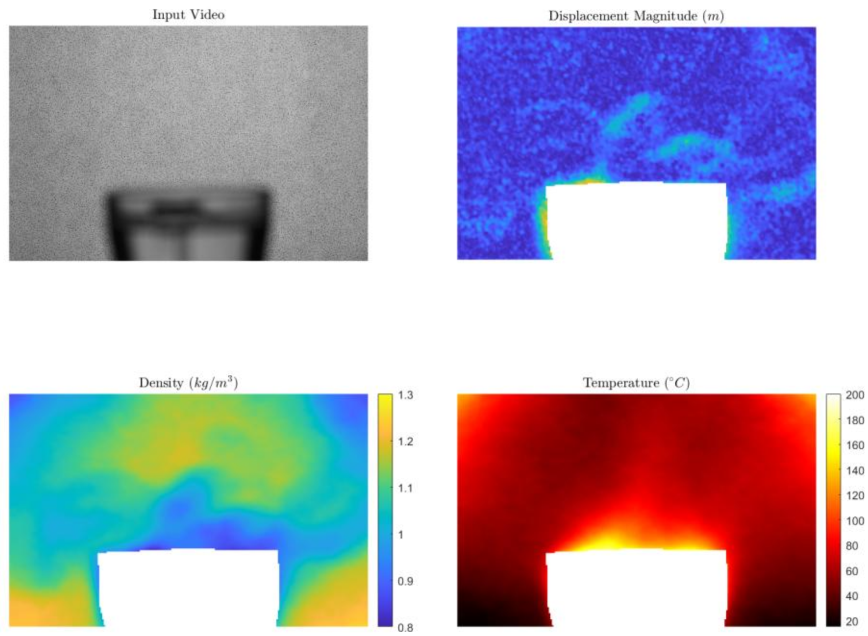


Figure 11: Reconstruction frame.

- For any further explanation or clarification, please see the software demo video posted to the GitHub site.