Ferrofluid oscillator: Measurements and data processing

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Measurements

Read the instructions carefully before starting!

You will use Casio Exilim EX-ZR300 –camera to record high-speed videos (1000 fps) of the oscillations of the ferrofluid droplet. The important buttons on the camera are showed in Fig 1.

Figure 1: Video preview and important buttons on Casio Exilim EX-ZR300

Recording Calibration Video

For the data analysis you will need to know how many pixels is one millimeter on each recorded video.

Instructions:

1. Position the glass slide above the main magnet (vertical distance ~2 mm).
2. Make sure the slide is precisely horizontal by e.g. pipetting several water droplets on the surface. If all the droplets roll off the same direction, the slide may be tilted.
3. Turn on the LED-panel.
4. Turn on the camera and verify that 1000 fps high speed video is selected: press *MENU* and check that video quality is *HS1000*.
5. Select super macro mode and manual focus: press *SET*, use control buttons (the ring around *SET* button) to scroll down to focus section (probably showing *AF*), select *Super Macro* and press *SET*. The camera is now in super macro mode. You also need to select manual focus: change the focus setting again as before, but this time select *Manual Focus* (*MF*).
6. Position the camera horizontally ~10 mm from the edge of the glass slide. You can use Blu-Tack at the bottom of the lab jack to keep it in place.
7. Adjust the height of the lab jack so that you can just see the slide in the bottom of the video preview part of the screen (the narrow non-shaded area in the middle of the camera screen, see Fig. 1). Make sure there are no dark objects on the background except for the glass slide.
8. Pipet a 10 µl ferrofluid droplet on the surface above the magnet. The magnetic field keeps the droplet in place.
9. Focus the camera on the droplet by pressing left or right on the control buttons.
10. Bring a ruler **directly above** the droplet, parallel to glass slide. In the camera screen you should see about 30 mm part of the ruler in the video preview area. Be careful not to touch the coating. The droplet doesn't have to be visible in the video, just the ruler above the droplet.
11. Take a short video where you can see the ruler (Fig. 2) by pressing *MOVIE* button (red circle).
12. Carefully remove the ferrofluid droplet from the surface with the pipette.
13. Do not move the camera after this (except vertically), or you might have to do the calibration again. If you accidentally move the camera, you can try to reposition it: pipet a ferrofluid droplet on the surface above the magnet and move the camera to a position where the droplet is again perfectly in focus.

Figure 2: *Calibration video*

Recording the Oscillations

General tips:

- It is wise to use team effort in the measurements: for example one student could work with the pipette and the auxiliary magnet, second the camera, etc.
- Because the coating is not perfectly homogeneous, all the measurements are supposed to be done at a single spot on the surface. **Be careful not to change this spot when adjusting the height of the slide!**
- Be careful not to move the camera when using the buttons, or you might have to redo the calibration.
- The camera screen will shut down when the camera is not used. Press any button (except on/off button!) to turn the screen on again. If the screen is allowed to stay off too long, the whole camera will shut down, and you need to focus it again.
- Make comprehensive notes while recording (such as distance between glass slide and magnet, were there any problems etc.). **Make sure you are able to link your notes with the video files after the measurements! Best way to do this is to number and describe each and every recorded video** (even unsuccessful ones) in the notes. It is also a good idea to check from time to time the number of the video file from the camera and write it down in the notes. You can do this by pressing the green *PLAY* button. To get back to recording mode, press *REC* button (showing a red camera).

The oscillations are recorded at multiple (3 – 5) separations between the magnet and the droplet. Depending on the surface, the usable separations are between 2 – 15 mm. It is better to start from a small separation. Several (3 – 5) measurements are repeated at each height:

1. Make sure that the camera, the LED-panel and the glass slide are ready to be used (see calibration).
2. Check that the horizontal distance between the axes of the auxiliary and the main magnet is about ~20 mm. If it needs adjustment, ask the assistant.
3. Measure the distance between the top of the main magnet and the top of the glass slide with a ruler and write it down.
4. Lift the auxiliary magnet until it almost touches the glass slide and keep it there.
5. Carefully pipet a 10 µl ferrofluid droplet on top of the auxiliary magnet.
6. Start recording.
7. Slowly lower the auxiliary magnet until the droplet is released and starts to oscillate around the main magnet axis. Observe the droplet from above to make sure it oscillates linearly back and forth (not on an ellipsoidal trajectory).
8. Stop recording when the droplet stops.
9. Remove the ferrofluid droplet.
10. If the oscillation was not linear you need to repeat the measurement after improving the setup:
    - Make sure the slide is precisely horizontal.
    - Try a different spot on the slide.
    - Bring the auxiliary magnet closer to the main magnet. If this is not possible, decrease the distance between the glass slide and the main magnet.
11. Repeat the measurement 3 – 5 times.
12. Change the height of the glass slide. Be careful not to move the slide horizontally. Then continue from step 3. Do the measurements in 3 – 5 different heights (remember to write down each height!).

Data Processing

After the measurements transfer the video files via USB-cable to the laptop in folder *OscillatorData* at the *Desktop*. Turn off the camera to save the battery. The video files are processed with Matlab.

Calculating Calibration Constant

Calibration video is used to determine how many pixels is one millimeter on the video:

1. Open the video using *VLC* (right-click on the video file → *Open with* → *VLC media player*.
2. Make sure the video is not stretched or zoomed in: *Video* → deselect *Always fit window*.
3. Find a point on the video where the ruler is clearly visible and horizontal (see Fig. 2). If this is not possible, you have to rotate the video: *Tools* → *Effects and filters* → *Video effects* → *Geometry* → *Rotate* and select appropriate angle.
4. Take a screenshot of the video: *Alt + Prt Sc* (i.e. *Alt + Fn + Insert*).
5. Open *Paint* (*Start* menu – *All Programs* – *Accessories*).
6. Paste the frame in the image (*CTRL+V*). Use *Magnifier* tool to zoom in (but do not use *Resize*).
7. Use *Selection* tool to select an area of certain width in the image (e.g. 20 mm) based on the ruler markings. In the bottom part of the window you see the dimensions of your selection in pixels. Write down the width of the selection in both pixels and millimeters. Calibration constant, which is used in the analysis, is the width in millimeters divided by the width in pixels.
8. Save the image, as it will be added to the report you write.

Extracting Droplet Coordinates

The measurements are processed with Matlab using custom functions. The functions rotate and crop the videos if needed, convert them black-and-white and recognize the droplet from background. The functions are in folder *OscillatorFunctions* at the *Desktop*, so change your Matlab working directory to that. Instructions for the functions can be viewed with *help* command (e.g. *help TestImageRecognition*).

First you need to set the image recognition parameters with function *TestImageRecognition*. The function loads a single frame from a video, rotates it and lets you interactively choose the threshold value for black-and-white conversion and crop the video. The input parameters are the name of the video file (with path), frame number, minimum black area that is interpreted as a droplet on the video and the rotation angle. Output parameters are the threshold value and cropping amount. The function can be used as follows (here 1000 is the frame number, 100 the minimum area interpreted as a droplet and 0 is the rotation angle):

[threshold, crop] = TestImageRecognition('..\OscillatorData\CIMG1234.avi',1000,100,0);

1. Choose the threshold value by moving the slider in *Intensity Distribution* (see Fig. 3). Choose the value so that the background in *Segmented* figure is completely white, while the droplet stays black. Substrate can remain black, it will be cropped away in the next step. Press *Done* when done.
2. Crop the image by dragging a rectangle around the droplet so that the black substrate is left outside the selection (see Fig. 4). Only the part below the selection is cropped away, so the positions of the side and top edges do not matter. Double click inside the cropped area to confirm the selection.
3. The function returns the threshold value and the height of the area cropped away, which will be used when extracting the coordinates from the video.
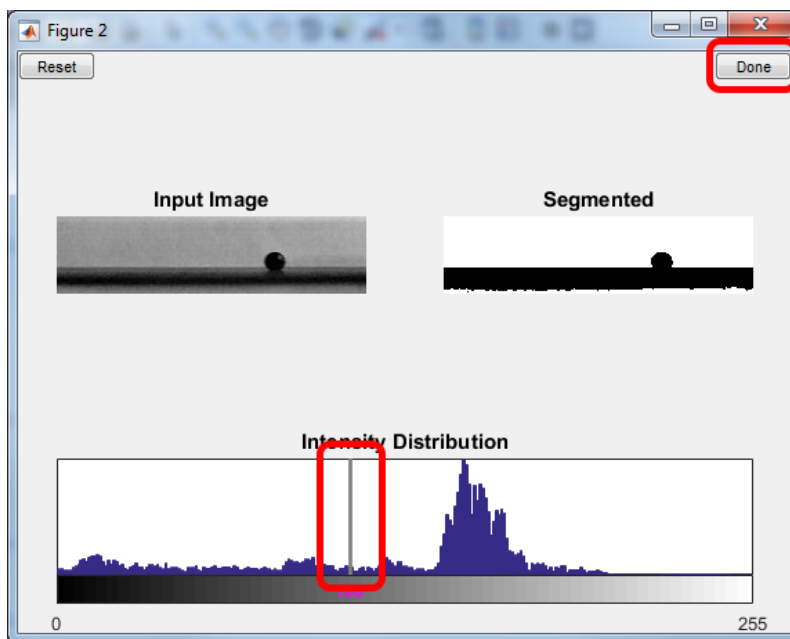

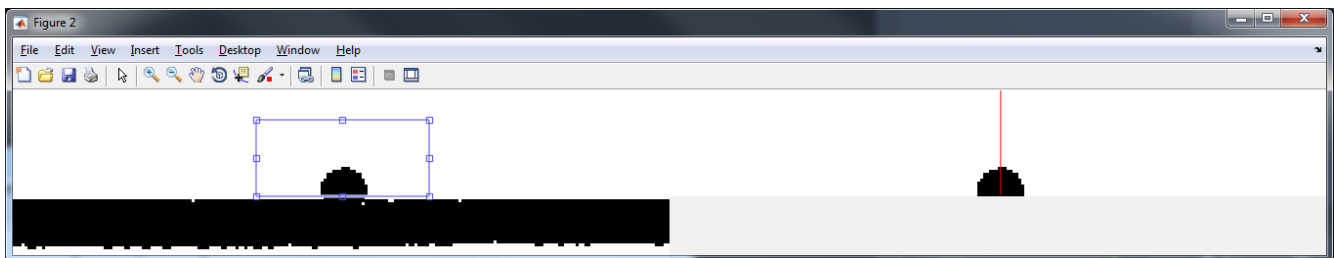*Figure 3: Choosing the threshold value*

Figure 4: Cropping the image

If your video is significantly tilted, you need choose a non-zero tilting angle (in degrees) when calling *TestImageRecognition*. Play around and see which value looks the best.

Coordinates are extracted with a function called *ExtractCoordinates*. Instructions for the function can be viewed with command *help ExtractCoordinates*. You can run the function only on a selected part of the video (i.e. the part where the droplet moves), by choosing the *first* and *last* frames when calling the function. This reduces the time it takes to extract the coordinates. You can check the approximate frame numbers using VLC (the video playback speed is about 30 fps, so 33 seconds equal ~1000 frames). Save the coordinates in a reasonably named variable. If you have numbered the measurements in your notes, you can use the same numbering to name your variables.

Set the image recognition parameters and extract the coordinates from all the relevant video files and save them in a Matlab file. You will analyze the data at home (separate instructions are in MyCourses), so make sure you have a copy of the data including the calibration image (use memory stick, e-mail or a shared folder). You will need to know the distance between the magnet and the droplet for each set of coordinates, so make sure you write them down.