Droplet Volume Calculation

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1 Introduction

This document explains the process used for calculating the volume of small droplets shed from a large droplet after it hits a surface. The goal of this analysis is to study the volume loss during droplet breakup by comparing the total shed volume with the difference between the initial and final volume of the large droplet. The process involves several stages, including frame extraction, filtering, droplet detection, and volume calculation.

2 Steps in the Process

The following steps outline the process for calculating the droplet volume:

1. **Frame Extraction:** We begin by extracting frames from a video or images. One frame is taken every 15 seconds to capture the droplet dynamics over time.
2. **Fourier Transform and Filtering:** Once the frames are extracted, we apply a Fourier Transform to each image to enhance the visibility of the droplets and reduce background noise.
3. **Droplet Detection using Connected Components:** After filtering, we detect the individual droplets in each frame by identifying connected components and measuring their areas.
4. **Volume Calculation:** The areas of the droplets are then used to estimate their volumes under the assumption that they are spherical. The total volume of droplets for each frame is calculated, followed by the total volume across all frames.

3 Fourier Transform and Filtering

Fourier Transform is a mathematical technique that transforms an image from the spatial domain into the frequency domain. In the frequency domain, the image is represented as a sum of sinusoidal components (frequencies).

We perform a *high-pass Fourier filter* to remove low-frequency components (such as smooth backgrounds) and retain high-frequency components (which correspond to sharp edges and fine details). This is achieved by applying a circular mask in the frequency domain, which suppresses the low-frequency components. After applying the filter, we perform an inverse Fourier Transform to convert the image back into the spatial domain, where the high-frequency components (the droplets) are now more visible.

4 Connected Components and Droplet Detection

Connected components analysis is a method used to detect regions in an image that are connected to each other based on pixel connectivity. In the context of droplet detection, the method identifies groups of adjacent pixels that share similar characteristics, such as intensity or color.

After performing some preprocessing steps like Gaussian blur and thresholding, we use connected components analysis to detect the droplets. Each connected component represents a droplet, and we measure the area of each component to estimate its size. We then filter the droplets by size to eliminate noise or too small droplets that are not relevant to our analysis.

5 Volume Calculation

Once we have the areas of the droplets, we assume that each droplet is spherical. Using this assumption, we can estimate the volume of each droplet using the formula for the volume of a sphere:

$$V = \frac{4}{3}\pi r^3$$

where r is the radius of the droplet, which can be calculated from the area using the formula:

$$r = \sqrt{\frac{\text{Area}}{\pi}}$$

The volumes of the droplets in each frame are summed to calculate the total volume for that frame, and the total volume across all frames is calculated to obtain the overall shed volume.

6 Summary of the Steps

The following steps summarize the entire workflow:

1. Extract frames from the input video or images.

2. Apply Fourier Transform filtering to enhance droplet visibility and reduce noise.
3. Use connected components to detect and measure droplets in each frame.
4. Calculate the volume of each droplet based on its area.
5. Sum the droplet volumes for each frame and across all frames.

7 Conclusion

This method provides a detailed analysis of the volume of droplets shed from a large droplet after it hits a surface. By combining Fourier Transform filtering, connected components analysis, and volume calculations, we are able to accurately measure the volume of small droplets and study the breakup process.