Smoke Point Report

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1 Smoke Point

Determining the smoke point in a combustion process is important because from that point onward the combustion emits smoke. Smoke indicates a incomplete combustion and heat loss.

A method to automatically determinate the smoke point is described on [2]. Image processing is used to determinate the flame shape. Then the ratio between the flame tip height and width is calculated and plotted fig 1

A Python code is developed mimicking the one described on the paper. It follows these steps:

- Transform the input RGB image into a Grayscale image
- Create a mask by thresholding with value th (depends on the brightness of the flame)
- Keep only the biggest blob. From it's bounding box we get the flame height H_f and flame width W_f.
- Calculate tip width as a percentage of flame width $W_t = wr * W_f$
- The flame tip height H_t is equal to the number of rows from the top of the bounding box until there is a row were the flame has a width equal or greater than W_t. W_t is updated with the width of this last row.
- Calculate tip ratio $R_t = H_t/W_t$
- Once R_t has been calculated for each frame, filter the resulting array of R_t with a weighted window.
- Plot $R_t vs H_f$ and fit two first order curves using PWLF[1].
- The intersection between this two curves is the smoke point.

The method to obtain the flame tip shape is different than the one described in [2] because the explanation is not clear. Also in the original paper, before filtering with a weighted window, points above (or below) the addition (or subtraction) of the mean and the standard deviation of the data are disregarded. This is not done here because this should be done around a neighborhood of each measurement (it is not described like this on the original paper but figure 2 shows this behavior). It seems that a proper implementation of this won't make a noticeable difference with the current data.

The points from flame height 1600 on-wards are not used when fitting the curves (Figure 1) because the flame is very unstable. This is currently hard coded.

The code needs some tweaks, but without a better video of a flame there is no point on doing so. Specially the filtering and how the data is plotted.

The method is sensible to the width ratio (Figure 3), but not so much to the threshold (Figure 4)

Code usage:

```
usage: smokepoint.py [-h] (-v VIDEO | -i IMAGES) [-t THRESHOLD]
                     [-r WIDTHRATIO] [-d] [-o OUTPUT]

optional arguments:
  -h, --help            show this help message and exit
  -v VIDEO, --video VIDEO
                        path to video
  -i IMAGES, --images IMAGES
```

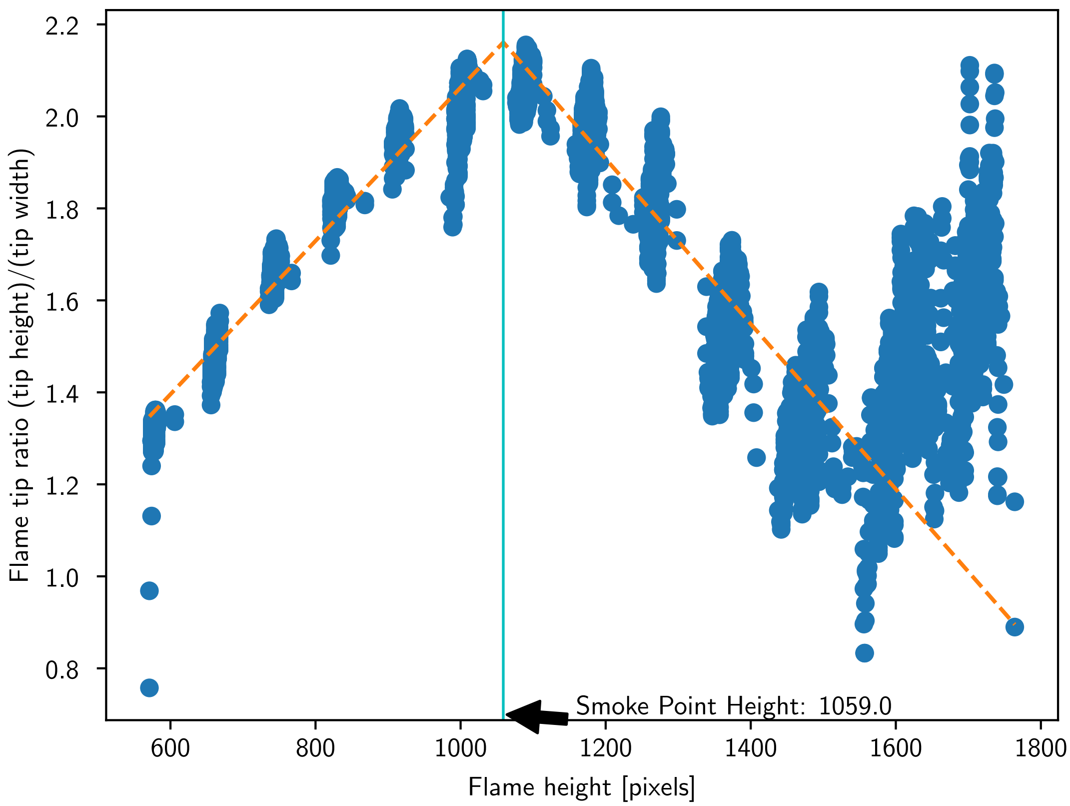

Figure 1: Results obtained with video recorded with a Basler monochromatic camera.

```
                        path to directory containing images (the names have to
                        be sorted alphabetically)
  -t THRESHOLD, --threshold THRESHOLD
                        threshold to separate foreground and background
  -r WIDTHRATIO, --widthratio WIDTHRATIO
                        tipWidth = flameWidth * widthRatio
  -d, --display         If used, displays flame
  -o OUTPUT, --output OUTPUT
                        Name of output plot
```

Example:

```
pipenv run python smokepoint.py -v input.avi -t 230 -r 0.3 -o smokepointTest -d
```

References

[1] Charles F Jekel and Gerhard Venter. pwlf: A python library for fitting 1d continuous piecewise linear functions. 2019.

[2] Guilllermo Rubio-Gomez, Lis Corral-Gomez, Jose Antonio Soriano, Arantzazu Gomez, and Fernando J Castillo-Garcia. Vision based algorithm for automated determination of smoke point of diesel blends. *Fuel*, 235:595–602, 2019.

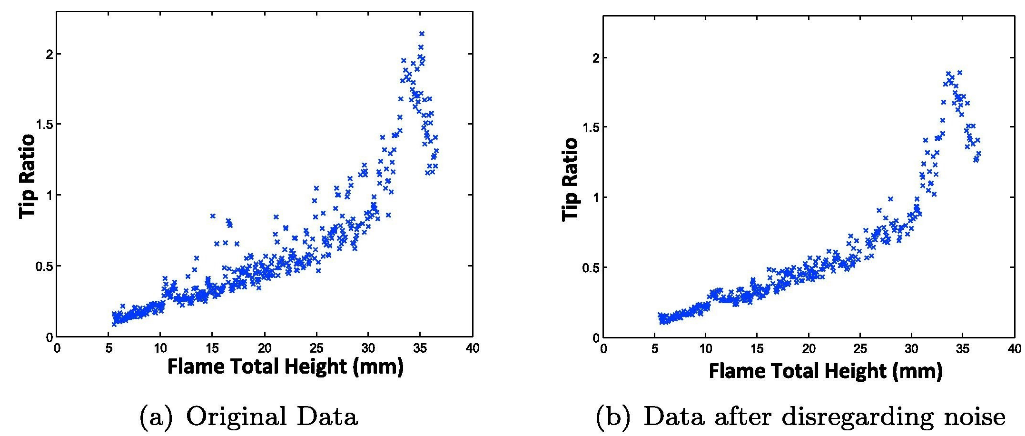

Figure 2: Figure from original paper filtering noise using mean and standard deviation

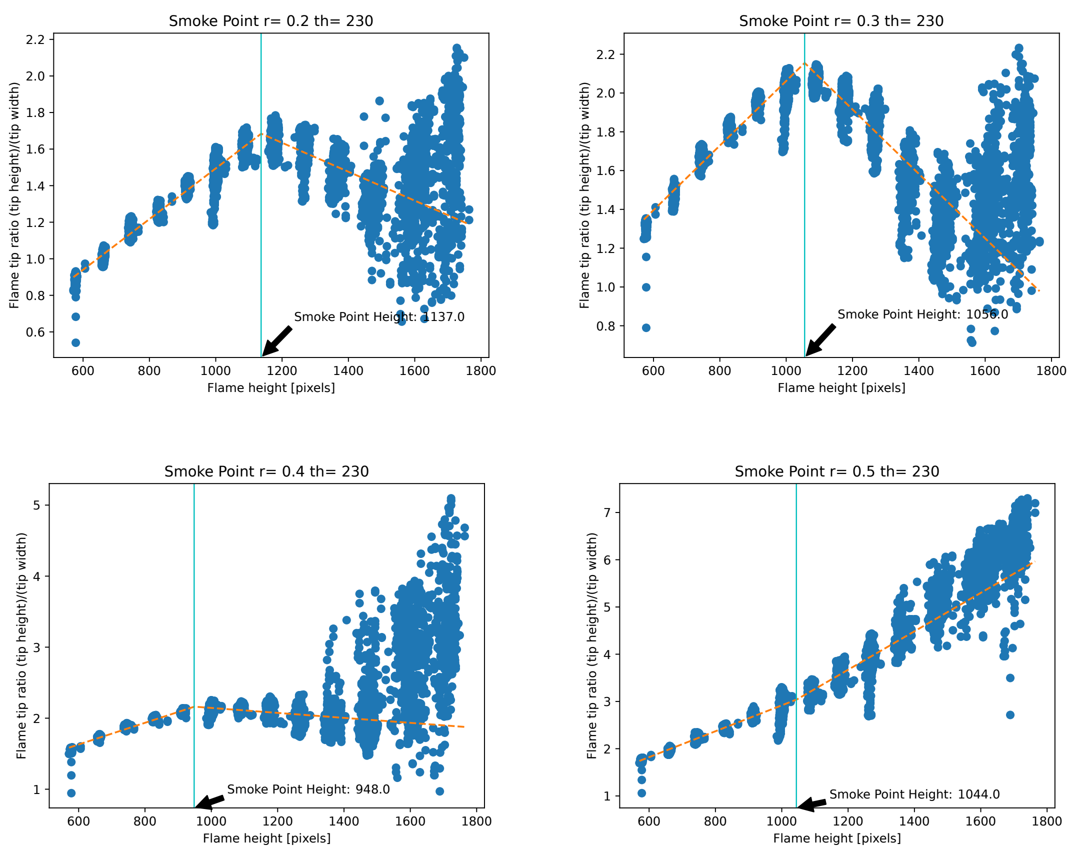

Figure 3: Smoke points for the same video for different width ratio (r)

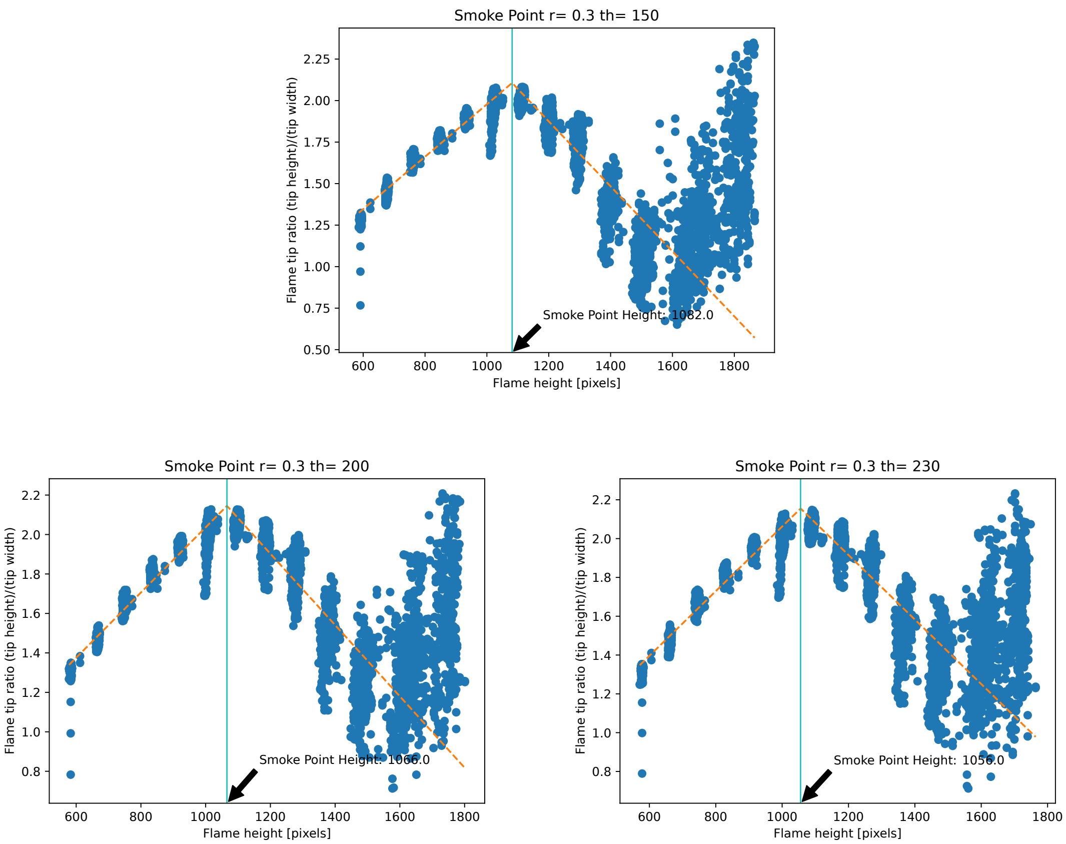

Figure 4: Smoke points for the same video for different thresholds (th)