Sensing Dust Concentration Through Imaging

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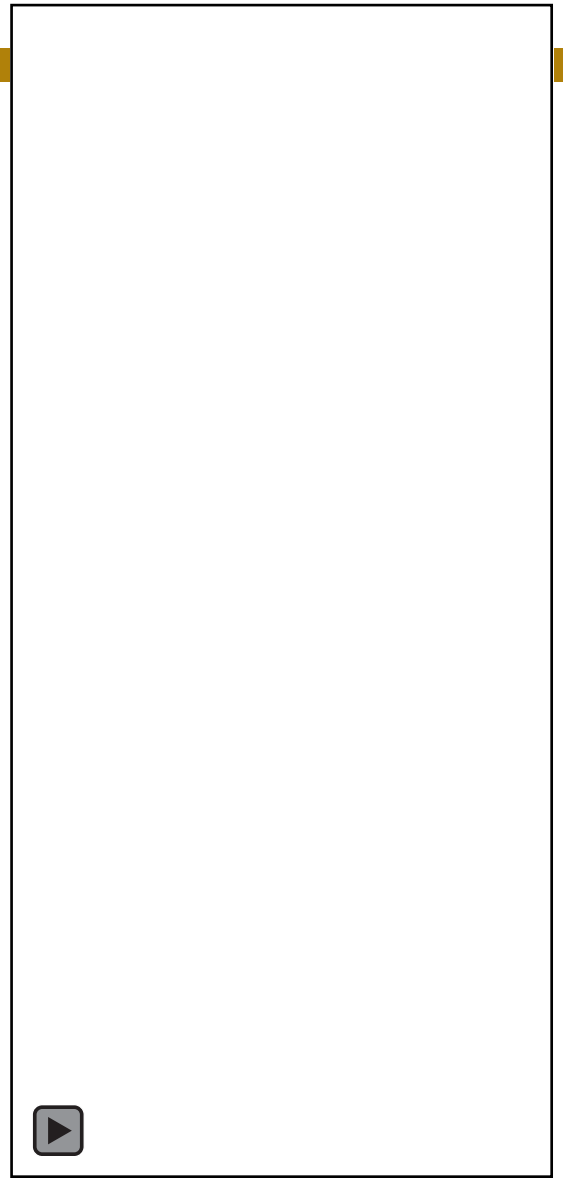
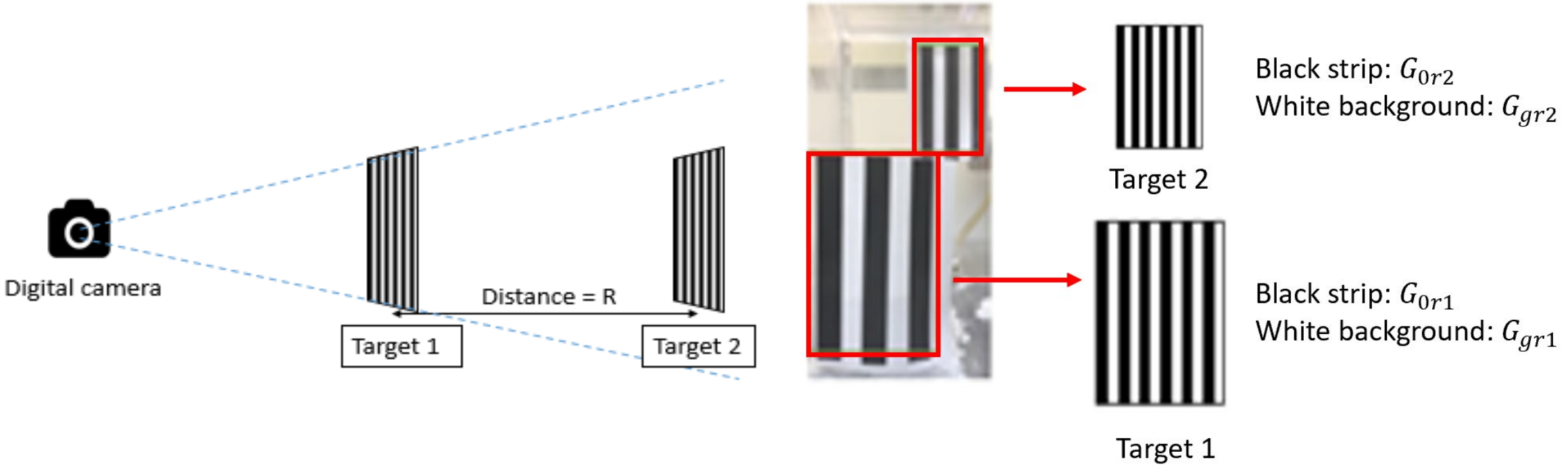
Recap



Recap - Method of Determination

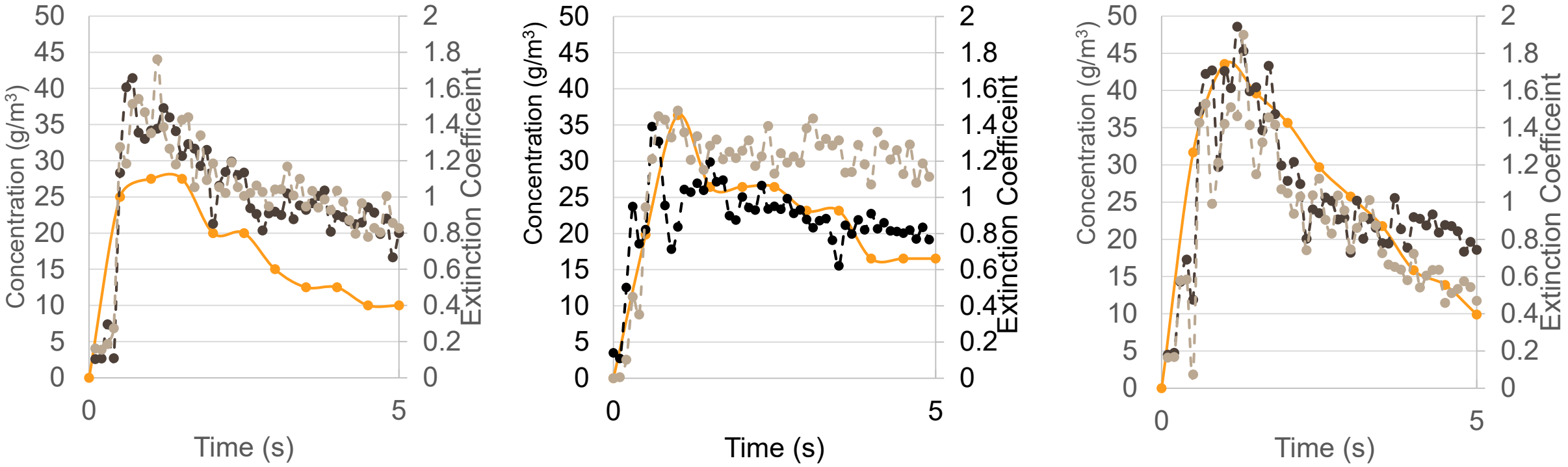


Schematic graphs of image sensing procedure

Samples Used:

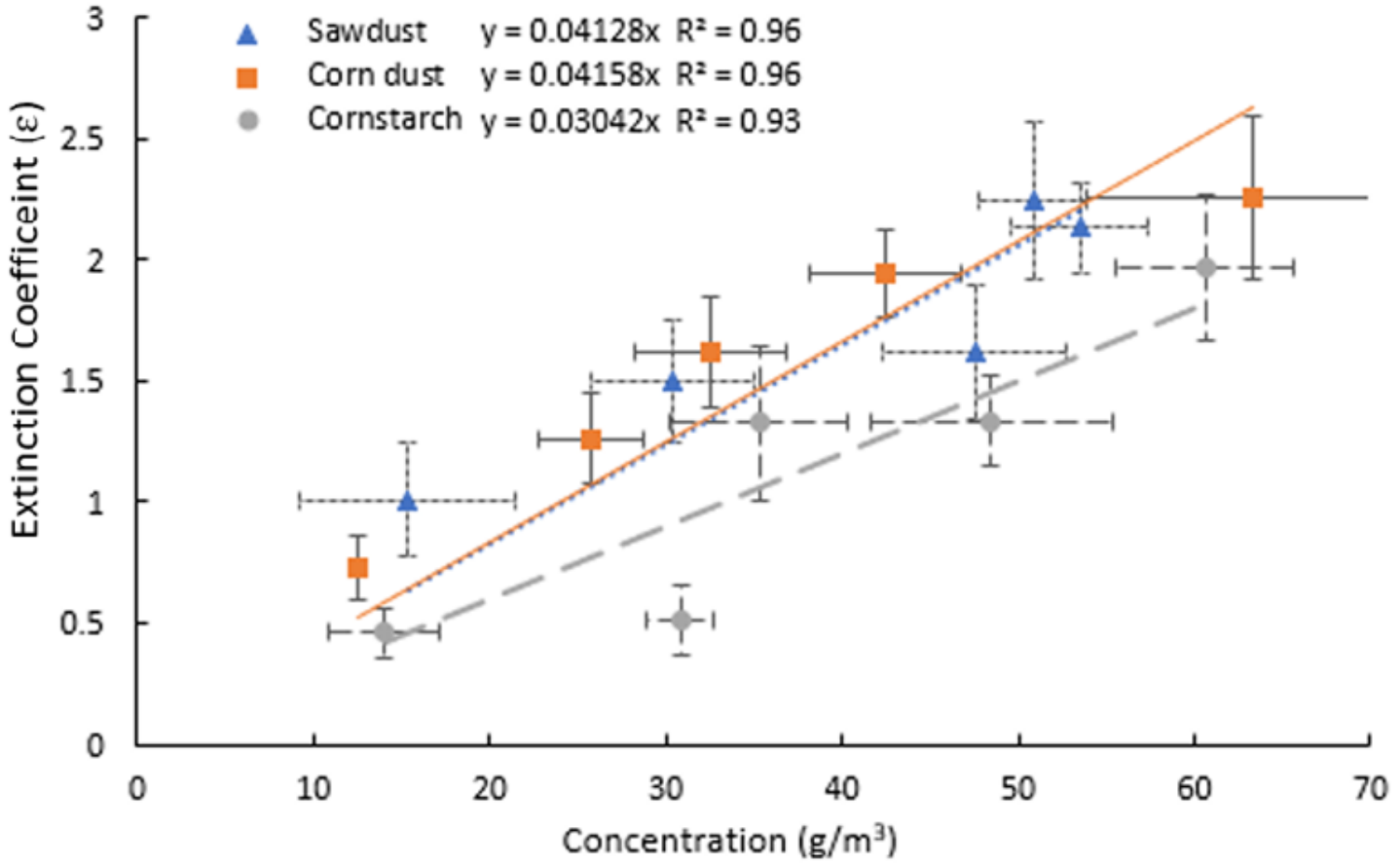
- Corn starch
- Corn dust (from local grain elevator)
- Sawdust

Recap - Extinction Coefficient During Dispersion



Extinction coefficient during dispersion. (Solid line is the laser measured concentration and dash line is the extinction coefficient of two replicates during dispersion) (left to right: Corn dust, Cornstarch, Sawdust)

Recap - Dust Concentration & Extinction Coefficient



Extinction coefficients for different concentrations

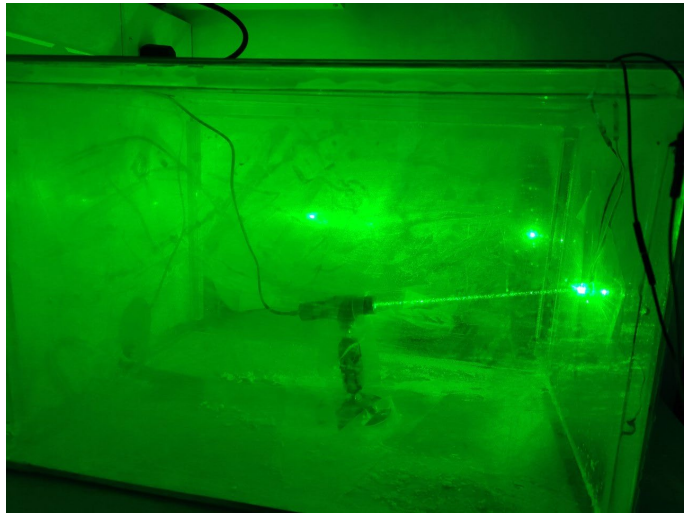
- Peak extinction coefficients (5 data point/0.5 s interval) were used to calculate the average extinction coefficient.
- R^2 >0.96 for saw dust and corn dust, R^2=0.93 for cornstarch

Challenges with Sensing from Images

- Effect of light conditions (light color, intensity, direction) on the accuracy of determination
- Effect of particle properties on light extinction coefficient

Dust Dispersion

- 0.5 – 2.5 g of powder dispersed in a 0.3×0.3×0.45 m^3 plexiglass chamber



➢ True Concentration: Measured using laser beam with photodiode. Data obtained every 0.5 s during dispersion

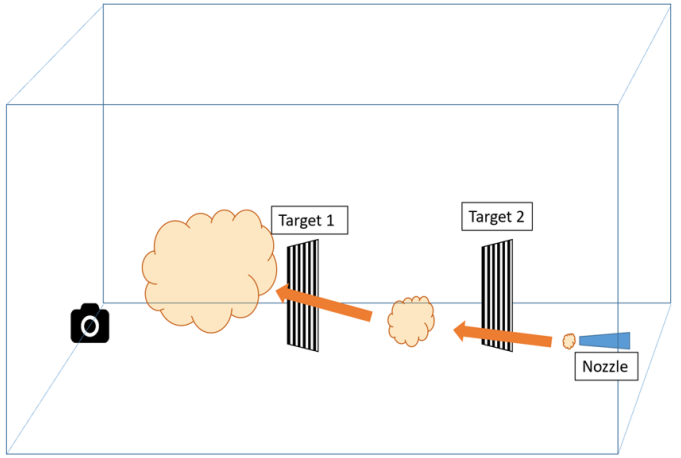
➢ Extinction Coefficient: Video captured using iphone 7 during dispersion at 60 fps. Frames extracted every 0.1 s to obtain extinction coefficient. Black strip separated from white background using image analysis (Otsu N,1979).

Effect of light condition on sensing efficiency

3 light conditions were tested for 1 and 2 g cornstarch dispersion (2 replicates)

1. Room light condition: Daylight tube light fixed in the ceiling, 615 LUX
2. Dim light condition: Warm white bulb fixed in the ceiling, 225 LUX
3. Dim light condition: Warm white bulb behind 2nd target, 345 LUX

1. Daylight
2. Warm white



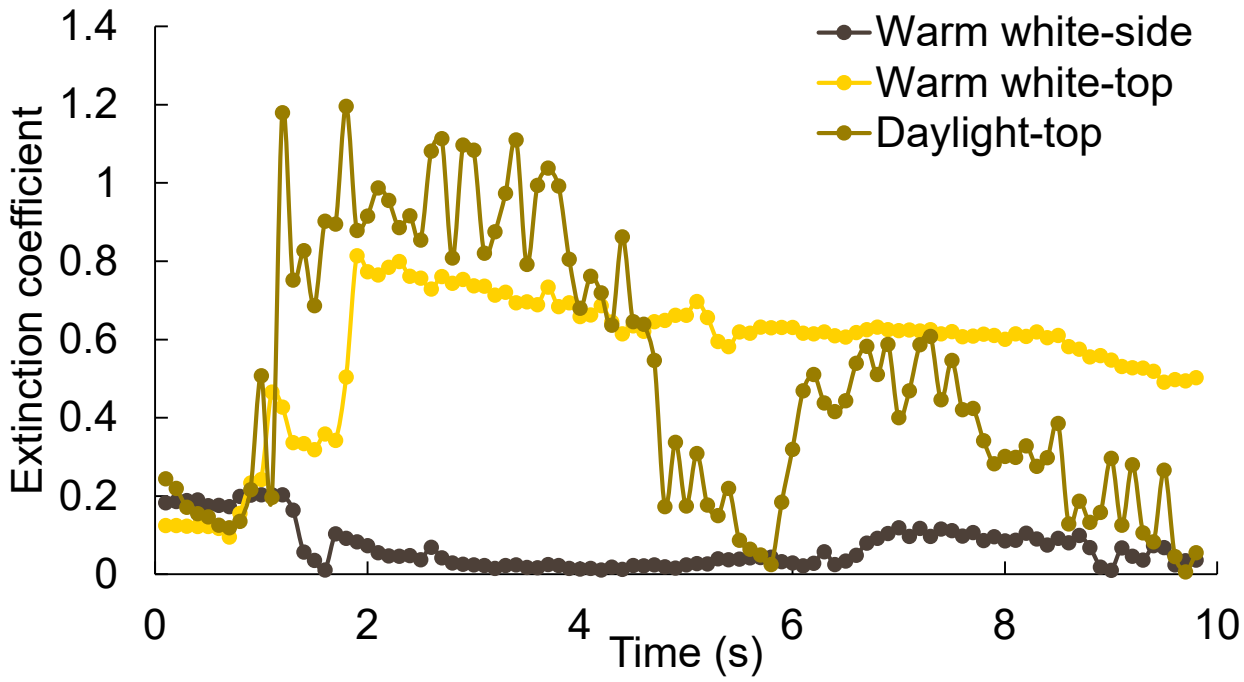
3. Warm white

Update

Change in Extinction Coefficient under Different Light Conditions

Dispersion amount (g)	Daylight, top	Warm white, top	Warm white, side
1	0.625 ± 0.425	0.281 ± 0.042	-------
2	0.979 ± 0.336	0.769 ± 0.025	0.0486 ± 0.0162

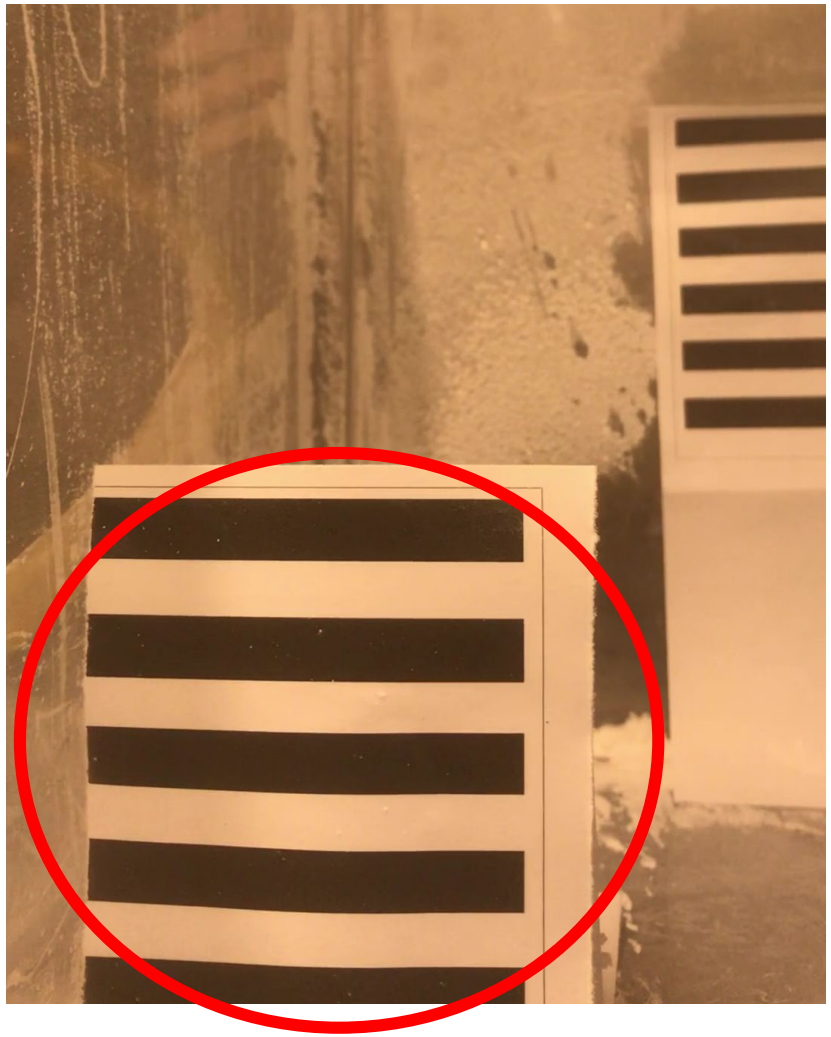
- Light intensity and light color have minor effect on dust extinction coefficient (not significant)
- Light direction affects the results – extinction coefficient dropped with dust dispersion



Extinction coefficient during 2 g dispersion.

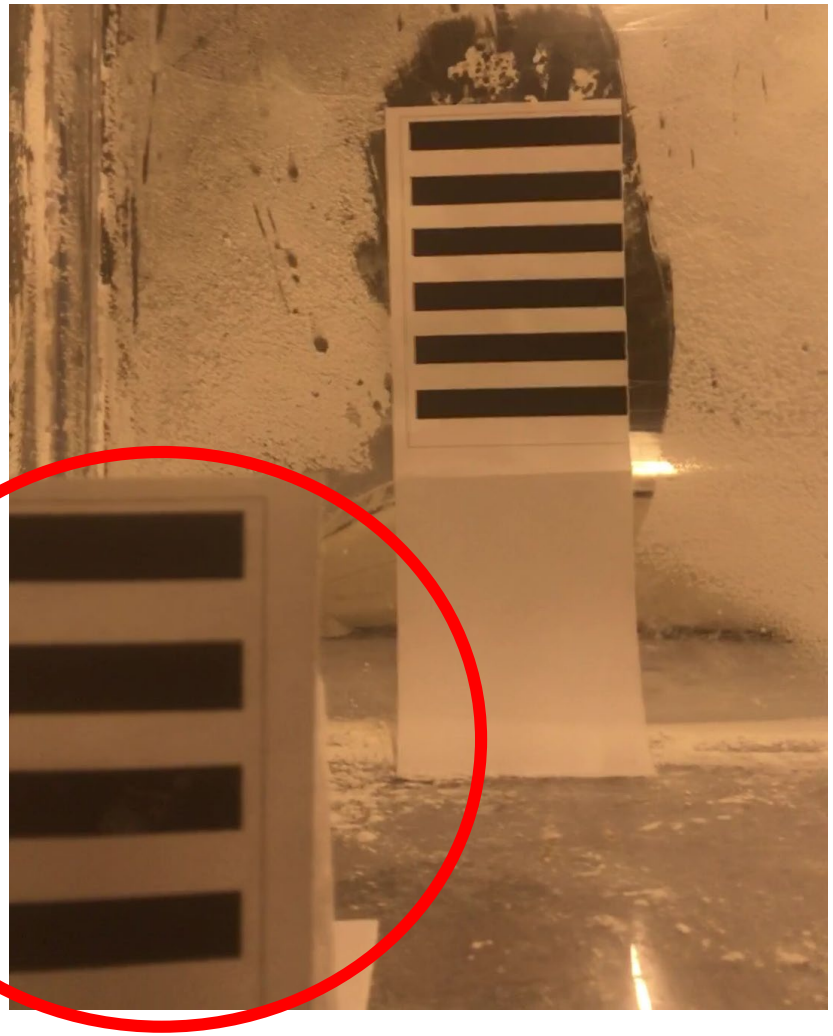
Effect of Light Direction

- Warm white – Top



Light direction affects the targets' intensity, thus a calibration before testing is needed

- Warm white – Side

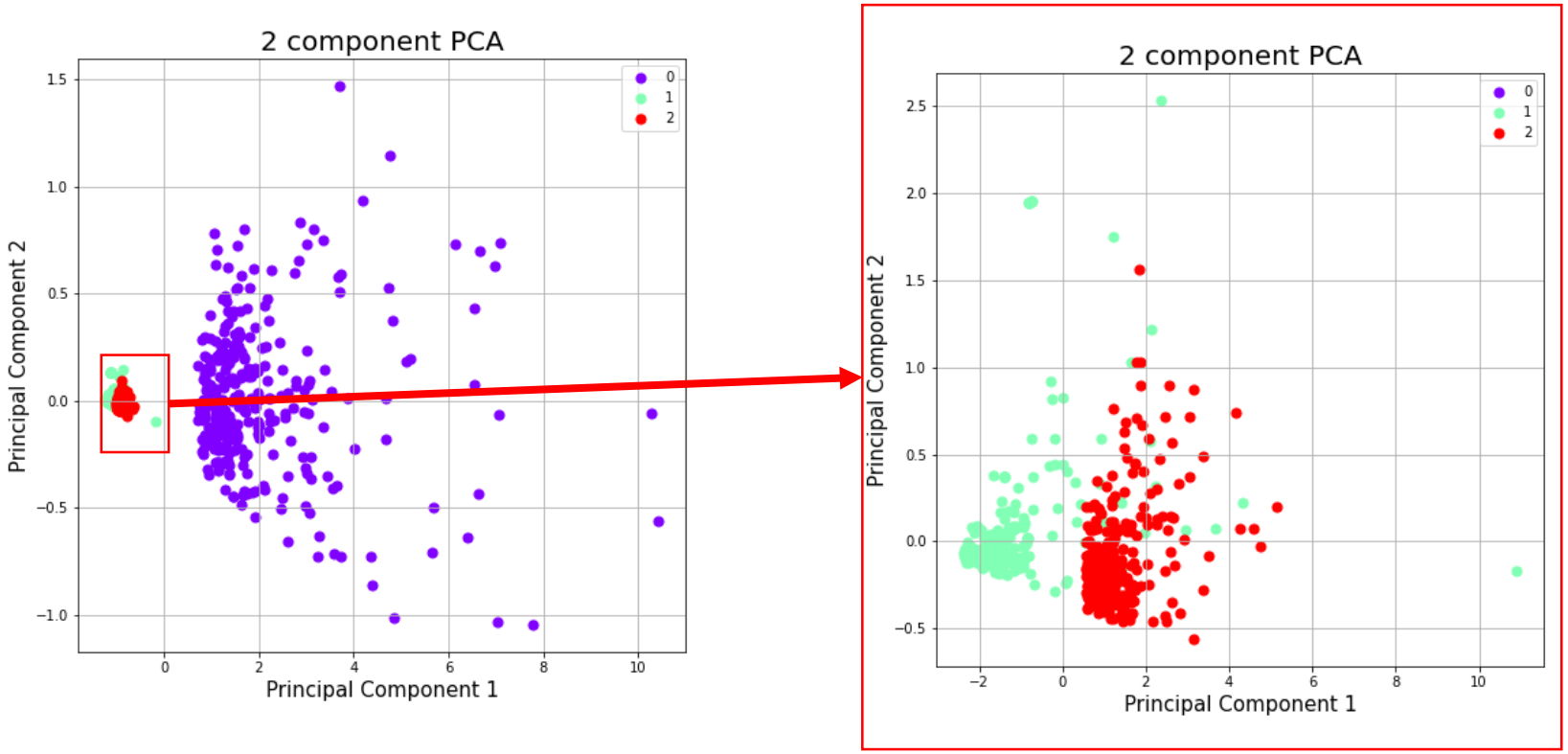


Dust Particle Properties on Light Extinction Coefficient (K)

- Dependence of K value on particle properties: 'CE Diameter (μm)', 'Length (μm)', 'Width (μm)', 'Max. Distance (μm)', 'Perimeter (μm)', 'Major Axis (°)', 'Area (μm²)', 'SE Volume (μm³)', 'Area (Pixels)', 'Circularity', 'HS Circularity', 'Convexity', 'Solidity', 'Aspect Ratio', 'Elongation', 'Intensity Mean', 'Intensity SD', 'Centre X Position (μm)'
- Principal component analysis: After removing outliers, 1700 particles for each sample and 18 features were selected and used for training

Most Influential Particle Properties

- CE-diameter, particle's width and length are the key factors influencing K value.
- Classification accuracy: 0.933



Classification of 3 dust samples using principal component analysis (PCA)

Conclusions

- Light intensity had less effect on the light extinction coefficient.
- Direction of incident light play an important role on measured dust concentration, a calibration is needed.
- Extinction coefficient will depend on dust particle diameter, width and length.

Update

Work in Progress

- Increase dust library, developing additional calibrations.
- Apply machine-learning to predict the dust's light extinction value for sensing and improve the accuracy of dust sensing.
- Develop a method to calibrate the targets based on light intensity.

Publication/Patent

- Zhao, Y., & Ambrose, R. P. K. (2020). A real-time method for sensing suspended dust concentration from the light extinction coefficient. *Journal of Loss Prevention in the Process Industries*, *67*, 104242.
- Ambrose, R. P. K., Zhao, Y., & Niu, Z. Sensing dust concentration through a mobile application. U.S. and WIPO utility patent application filed on 12/01/2020 (2020-AMBR-68881).

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Thank You!

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