Granulometric analysis of maltodextrin particles observed by scanning electron microscopy

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OBJECTIVE

Determining the **Particle Size Distribution** (PSD) of **condensed** and **overlapping** particles of maltodextrin in **grayscale images** observed by **Scanning Electron Microscopy** (SEM).

MAIN LINES

- **Implementing** grains **segmentation methods**.
- **Developing** a stochastic **grains simulation model**.
- **Comparing** methods **accuracy** on **simulated images**.
- **Applying** the methods on **real images**.

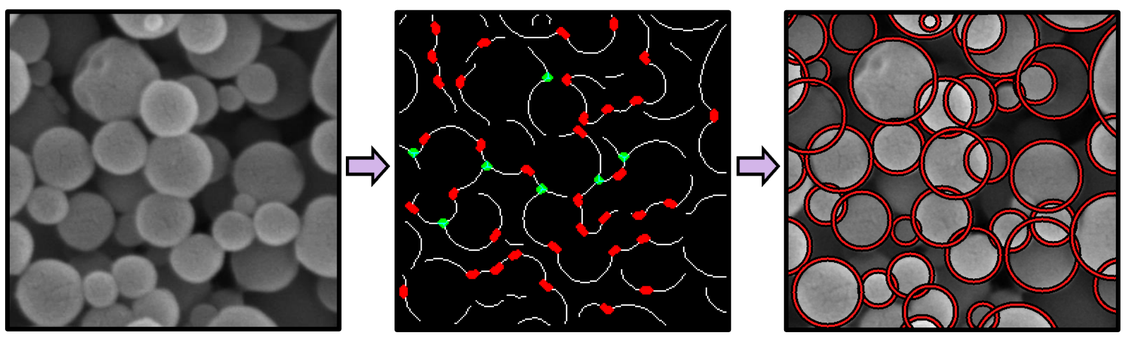
METHOD

Three segmentation methods

- **Stochastic Watershed** (SW).
- **Circular Hough Transform** (CHT).

Problem: either **over** or **under-segmentation**!

- Proposed: **Curvature Analysis Method** (CAM):

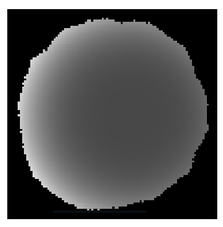


A real image | Analysis of the curvature of the contours' skeleton | Associated circles

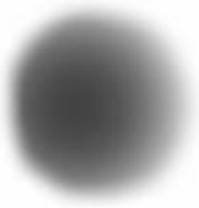
Grains simulation model

The model generates **random grains** and add them randomly on a black image **one after the other:**

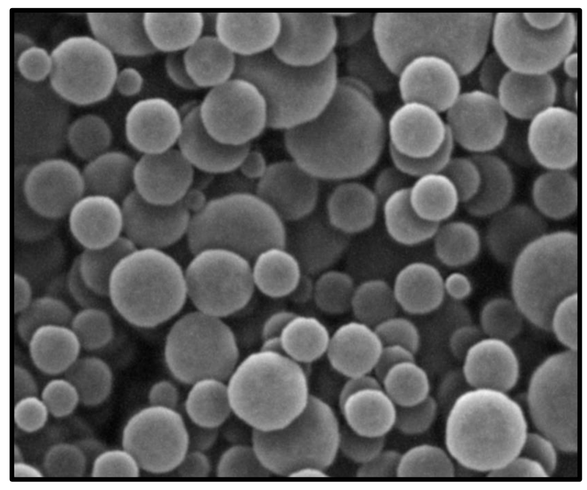
Random binary grain shape



Lighting effects added to shape



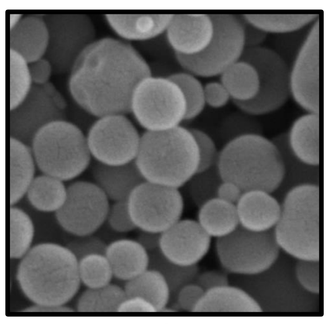
Grain shadow computed from shape and light source direction



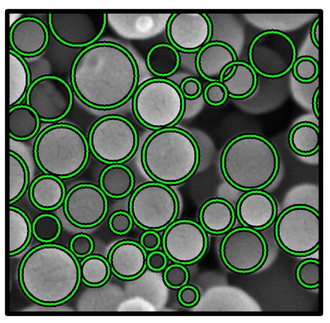
Final generated image with noise

RESULTS

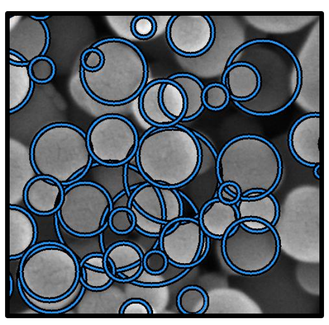
Visual comparison



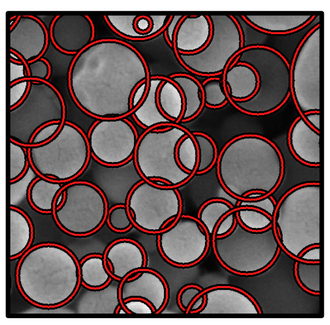
Original image



SW



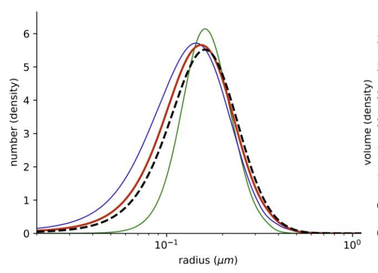
CHT



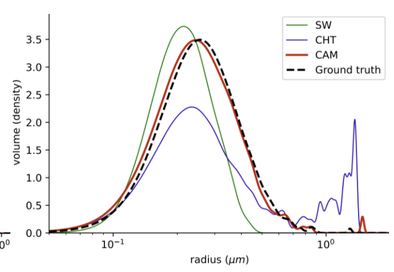
CAM

Densities comparison

The three segmentation methods are applied on **100 simulated images** from a **log-normal law**.



PSD in number



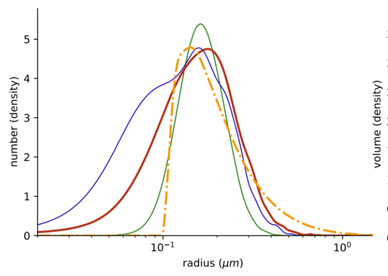
PSD in volume

Properties	Ground truth	SW	CHT	CAM
Mean	0.199 μm	0.187 μm	0.182 μm	0.190 μm
STD	0.082 μm	0.054 μm	0.104 μm	0.081 μm

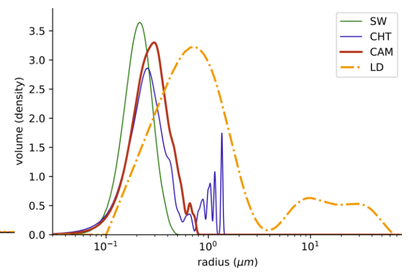
Means and standard deviations

Results on real images

They are applied on **20 real images** of maltodextrin particles, and compared to **Laser Diffraction** (LD).



PSD in number



PSD in volume

Properties	LD	SW	CHT	CAM
Mean	0.217 μm	0.185 μm	0.184 μm	0.207 μm
STD	0.133 μm	0.052 μm	0.105 μm	0.093 μm

Means and standard deviations

CONCLUSION

✓ In simulations, the CAM is more accurate than the SW and than the CHT in both PSD in number and PSD in volume.

✓ Based on the results given by the CAM, the grains from real images can be considered as following a log-normal law with a mean of 0.207 μm and a standard deviation of 0.093 μm.

✓ The laser diffraction can not be considered as a trustworthy granulometric tool as its PSDs are far from observation.

For a future work: try deep learning methods and compare the results to the ones obtained in this study.