# Evaluation of Deep Learning methods for particle characterisation from in-line imaging and chord length distribution measurements

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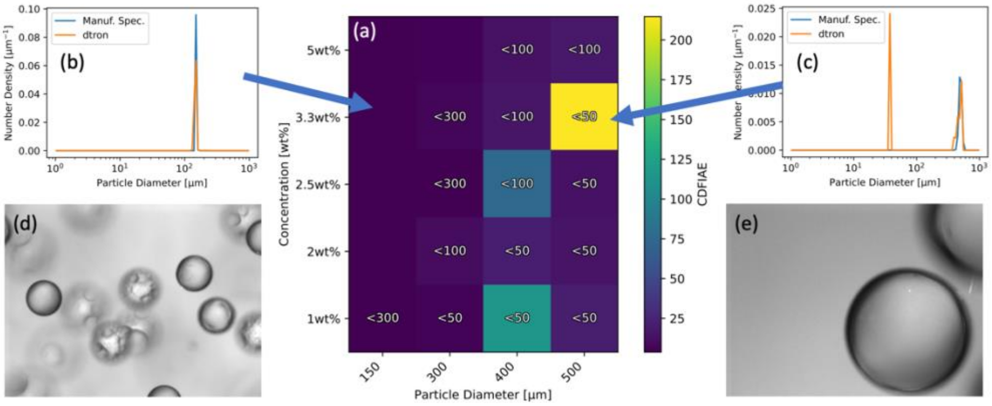


*Figure 1. Evaluation results: ML Image analysis applied to system of polystyrene standard spheres of different diameters at different concentrations. (a) Error matrix (Integral Absolute Error of Cumulative Density Functions). Numbers represent particle counts. (b)-(c) Specific examples comparing image analysis with manufacturer spec. (d)-(e) Example PVM images for examples in (b) and (c).*

In-line Process Analytical Technologies (PAT) are useful for measurement of particle characteristics (e.g. particle size distribution, PSD) non-destructively and with high time-resolution (inaccessible with off-line techniques) which can be essential for process monitoring and accurate population balance modelling.

This work is concerned with assessing in-line imaging and chord length distribution (CLD) for determination of PSD. Imaging is limited by resolution (small particles are difficult to measure), subject focus, and field-of-view (particles touching image frame). CLD sensors (e.g. focused-beam reflectance measurement, FBRM) can detect particles of smaller sizes but struggle with fast flow (undersized chords), large particles (chord splitting), and shiny particles (specular reflection).

In-line measurements were taken with the Mettler Toledo FBRM (CLD) and PVM (imaging) probes of Polystyrene Standard Spheres, a mixture of Polystyrene Spheres and Ellipsoids, and Lactose particles. In-line-derived PSDs from a range of crystal sizes and concentrations were compared with ground truth (off-line microscopy or manufacturer specifications) as shown in Figure 1. Image analyses include a machine learning (ML) method (Detectron 2 [1]) and a traditional approach (ImagingApp [2]). CLD analyses are based on a statistical approach [3], and a 1D convolutional neural network method. Sensors and analyses are evaluated using Root Mean Square Error (RMSE) and Integral Absolute Error (IAE) of the Cumulative Density Functions (CDFs).

Statistical CLD analysis is found to be sensitive to non-uniform particle shape distributions, and to artefacts introduced by the sensor. ML CLD analysis yields improved results, but is heavily reliant on the training data. The selection of image analysis approach has less of an effect on the resulting PSD than the characteristics of the image sensor itself where resolution and field-of-view limitations play a larger role – impacting measure of small and large particles respectively. Low concentrations present issues with detecting only few particles: limiting ability to form smooth PSDs.

### References

[1] Wu, Y., et al. 2019. Detectron 2. https://github.com/facebookresearch/detectron2

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[3] Agimelen, O. S., et al. 2015. Estimate of particle size distribution and aspect ratio of non-spherical particles from chord length distribution. Chemical Engineering Science, 123: 629-640.