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Particle agglomeration analysis using **PATVIS** APA and deep learning

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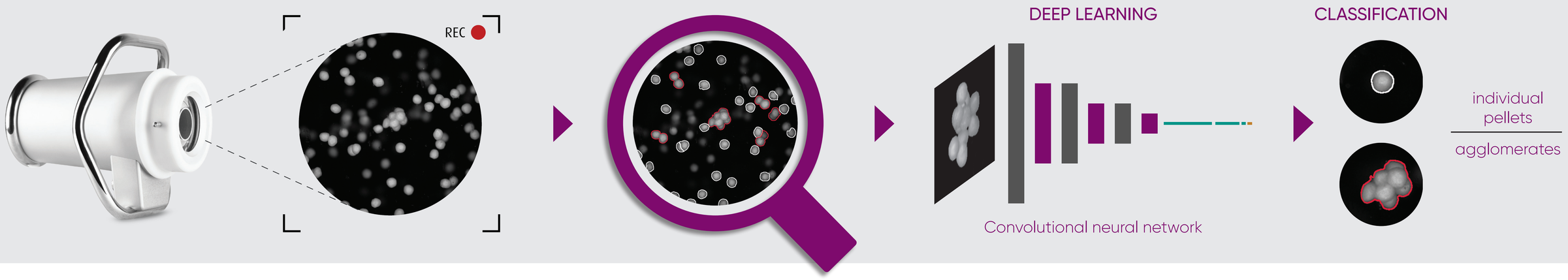
AIM

Develop and evaluate a deep learning approach for in-line recognition of agglomerated pellets and estimation of the agglomerate fraction with the visual inspection system **PATVIS** APA (Sensum, Slovenia).
Real-time:

- Acquisition of pellet images
- Recognition of single pellets and agglomerates
- Estimation of agglomerate fraction trends

INTRODUCTION

Agglomeration negatively affects the coating process yield (agglomerates are discarded) and the coat integrity.
Optical methods are currently the most promising approaches applied to pellet coating processes for in-line agglomerate fraction analysis.
Evaluation by comparison of the agglomerate fraction estimated by the novel in-line method to the reference values, which were defined by the prepared mixtures of individual pellets and agglomerates.



MATERIALS AND METHODS

AGGLOMERATE FRACTIONS

- Film-coated microcrystalline cellulose pellet cores with a size distribution 700 µm–1000 µm.
- 100 g reference agglomerate fraction mixtures of 0.0, 0.5, 1.0, 2.5, 5.0, 10.0, 20.0, and 100 % w/w, prepared by mixing agglomerates with individual pellets.

METHODS

IMAGING SETUP

Image acquisition in a simulator mimicking pellet movement during the coating process (i.e., 2D fluid-bed system) using an in-line visual inspection system **PATVIS** APA (Sensum, Slovenia).
Each agglomerate fraction mixture imaged for 10 min at a rate of 100 images per second, which resulted in an average sample size of 300 000 particles.
The acquired images split randomly to the learning and the evaluation images.

Figure 1: Image acquisition of pellets in a 2D fluid-bed system (right) with visual inspection system PATVIS APA (left).

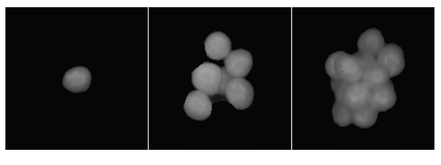


Figure 2: An individual pellet (left), a group of individual pellets (middle) and an agglomerate (right).

IMAGE ANALYSIS

- Detect particle regions.
- Classify as individual pellets, groups of individual pellets or agglomerates using a deep learning model, i.e. a convolutional neural network (CNN), trained on the acquired learning images.
- Estimate agglomerate fraction as the volumetric ratio between the agglomerated pellets and all analyzed pellets.

EVALUATION

Comparison to the reference mass values of the prepared mixtures and to the previously proposed in-line method based only on the pellet/agglomerate size [1].

RESULTS AND DISCUSSION

The agglomerate fractions measured with the CNN method show better agreement with the reference values (Table 1, Figure 3).

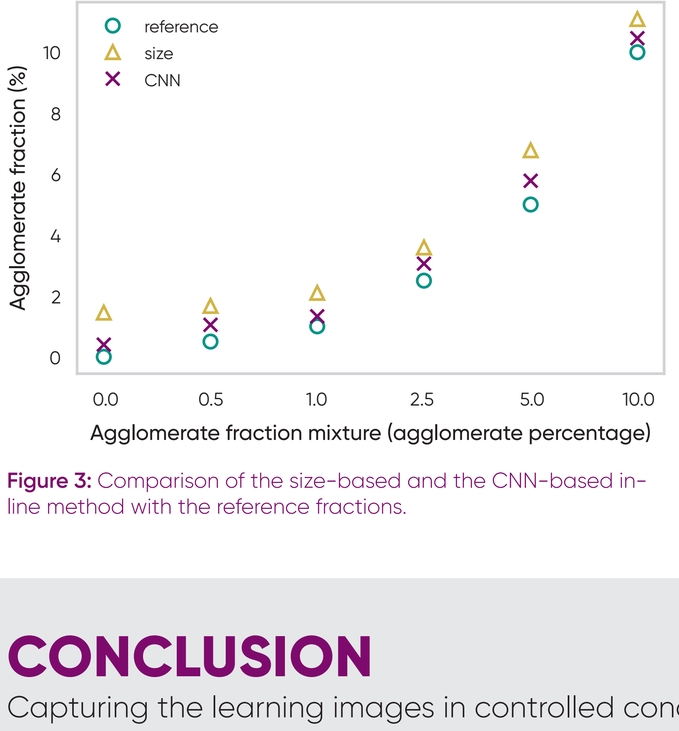


Figure 3: Comparison of the size-based and the CNN-based in-line method with the reference fractions.

Table 1: Results on mixtures with predefined agglomerate fractions (AF_{ref}): AF_{size} – agglomerates recognized based on their size, AF_{CNN} – agglomerates recognized with CNN.

AF_{ref} (%)	AF_{size} (%)	AF_{CNN} (%)
0.0	1.45	0.40
0.5	1.67	1.05
1.0	2.10	1.33
2.5	3.59	3.06
5.0	6.78	5.78
10.0	11.09	10.46
20.0	22.77	22.15
100.0	87.31	94.15
RMSE	**4.73**	**2.25**

The size-based method is less accurate at detecting low agglomerate fractions because of more false-positive agglomerate detections (Figure 4), where groups of individual pellets are falsely recognized as agglomerates.

ROC curves for classification based on estimated particle sizes by a previously proposed method [1] and based on the novel CNN method show a significantly better performance of the CNN classifier.

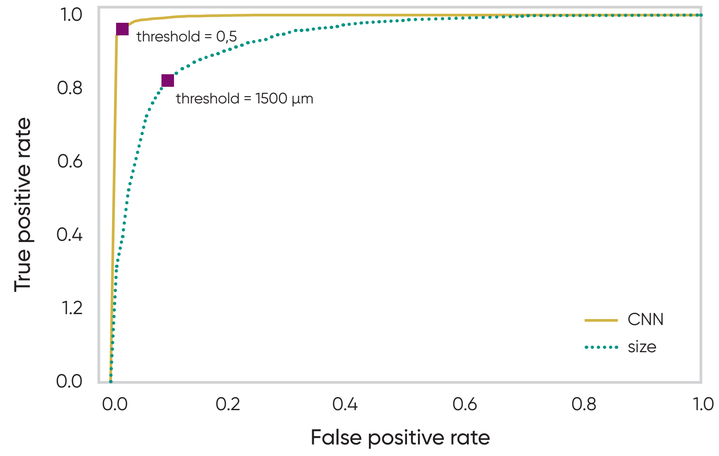


Figure 4: ROC curve for classification based on estimated particle sizes and based on the novel CNN approach.

CONCLUSION

Capturing the learning images in controlled conditions separately for individual pellets and agglomerates is a key step for the practical feasibility of using deep learning to identify agglomerates in actual pellet coating processes.
The timely agglomerate fraction measurements obtained by automated image analysis provide unprecedented information for understanding, controlling and optimization of pellet coating processes.

[1] A. Mehle, D. Kitak, G. Podrekar, B. Likar, and D. Tomaževič, "In-line agglomeration degree estimation in fluidized bed pellet coating processes using visual imaging," *Int. J. Pharm.*, vol. 546, no. 1, pp. 78–85, Jul. 2018.

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