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# Aerosol characterization on noisy surfaces by deep-learning methods

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Experimental studies to characterize aerosol deposition in flow system (such as ventilation duct) may require avoiding a sampling substrate which modifies the flow in the boundary layer, influencing the deposition or the interaction forces. However, measuring the deposition of aerosols on surface without any intermediate substrate presents detection difficulties (Costa *et al.* 2021) which can be overcome by direct visualization of aerosols by microscopy, using the microscope as a scanner. However, analysing the deposition of aerosols on any surfaces by microscopy generates certain constraints regarding the use of known visualization techniques: inhomogeneous image backgrounds due to the surface structure, unsharp images due to the non-flatness of the real considered surfaces. Common image processing is then not very effective.

The objective of this work is therefore to deploy advanced computer vision methods to process images acquired on typical surfaces of ventilation ducts (stainless steel).

Little work exists to date on the detection of aerosols using neural networks. Monchot *et al.* (2021) were interested in nanoparticles, as were Merouane *et al.* (2023) but in these works, the particles stand out relatively well from the background.

## Experimental set-up

An optical microscope is mounted on a 3-D micrometric displacement rail and is positioned above the surface to be analysed. The microscope has an autofocus system which allows it to obtain a sharp image by taking a “stack” of images in the depth of field. Thus, even if the analysis surface is not perfectly flat, the “image stack” makes it possible to obtain at least one sharp image.

A synchronization is developed specifically to allow the displacement of the microscope and the autofocus. A “scan” of an area of 2x2 cm<sup>2</sup> is obtained within 20 min. The magnifications used are x3.5 and x7, making it easy to distinguish particles, on a neutral background, down to 10 µm (resolution of 0.7 µm/pixel).

## Image processing

A convolutional neural network, Cellpose (Stringer *et al.* 2022), is used to process the acquired images. Cellpose is a convolutional neural network developed specifically for cell biology image segmentation and trained on a wide range of cellular data, as well as other images. This gives

it an ability to generalize and operate robustly on various types of images. The architecture of this network is based on a U-Net type network, particularly known in computer vision, often used for semantic segmentation tasks where the objective is to classify each pixel of the image into a region of interest. One feature of CellPose compared to a usual U-Net network is that it returns an instance segmentation, i.e. it is capable of separating two neighbouring particles from each other.

The quality of the segmentation is estimated by comparing the ground truth (the training images segmented by “hand”) with the areas detected by the CNN (or by traditional methods). Two types of metrics are calculated in terms of pixel (surface) or of objects (particles) and will be described in the presentation.

## Results

These metrics were calculated on a set of 1000 particles annotated manually and evaluated by the neural network. A very good performance is obtained with Cellpose, significantly higher than what is obtained by a traditional morphological method on these same images. The results demonstrate a high performance of the network, surpassing even that of inexperienced human annotators and details will be given in the presentation. Complementary to the mathematical performance of the network, it is appropriate to compare the overall technique (which includes both the mathematical performance of the network and the extrapolation of 2D images into a 3D result) to a reference technique used in aerosol metrology. To do this, particles analysed by this method are also analysed by a Coulter Multisizer and their total mass is measured on a micro-balance. The results obtained are within the range of uncertainty of these experimental methods. The performance of global method is satisfactory for a given particle size, which is encouraging for extrapolation to other particle sizes and other backgrounds/surfaces.

Costa D., *et al.* (2022) Measurement Science and Technology 33:9

Merouane S. *et al.* (2023) Congrès Français des Aérosols, Paris, France, Mars 2023

Monchot *et al.* (2022) Nanomaterials, 11, 968

Stringer, C. *et al.* (2021) Nat Methods 18, 100–106