Deep learning supported image analysis of angle-resolved scattered light images of bacteria in microfluidic droplets

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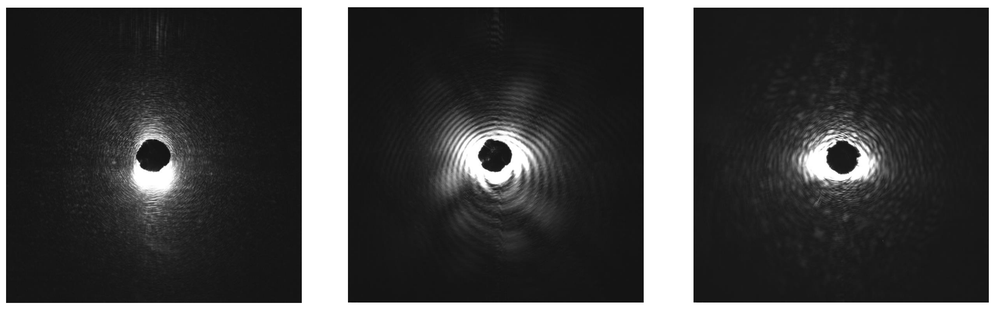
Microfluidic droplets and angle-resolved scatter (ARS) images

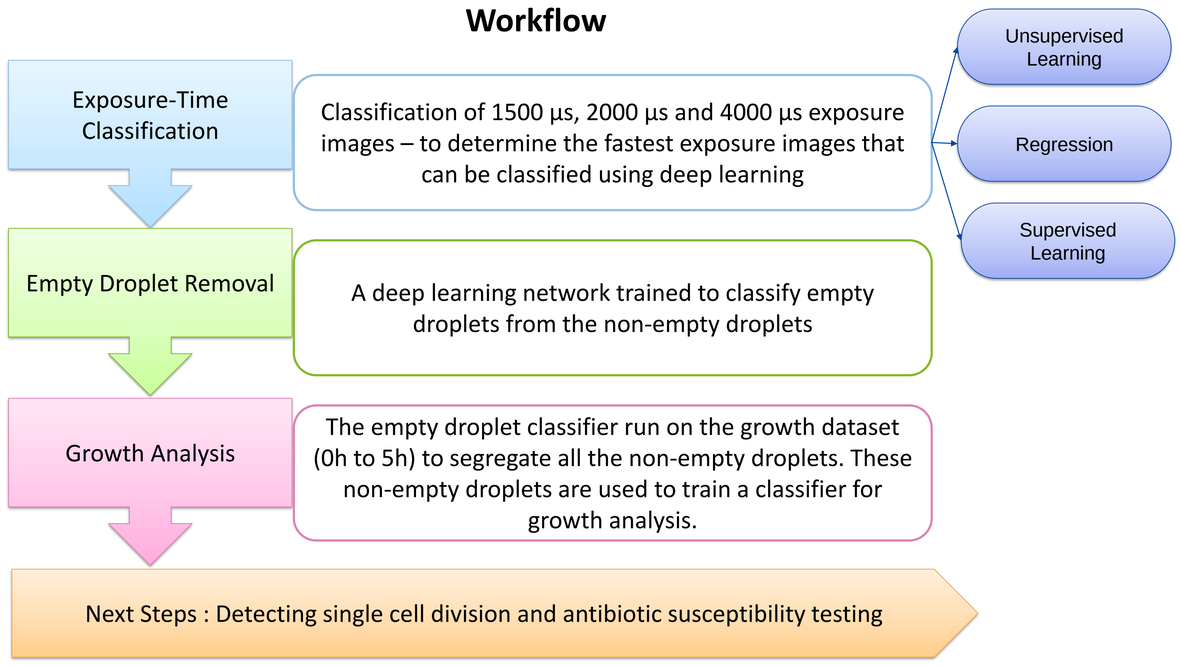
- Angle-resolved scattered light imaging (ARS) gives fast and highly resolved information about structures and objects [1]
- ARS applied to picoliter-sized droplets in flow to detect cell growth on a single-cell level (*E. coli* and *S. aureus*)
- Traditional image analysis and Deep Learning technique to quantify changes in spectra
- Goal is to detect single cell division events for rapid antibiotic susceptibility testing

ARS images of droplet with *S. aureus* and *E. coli*

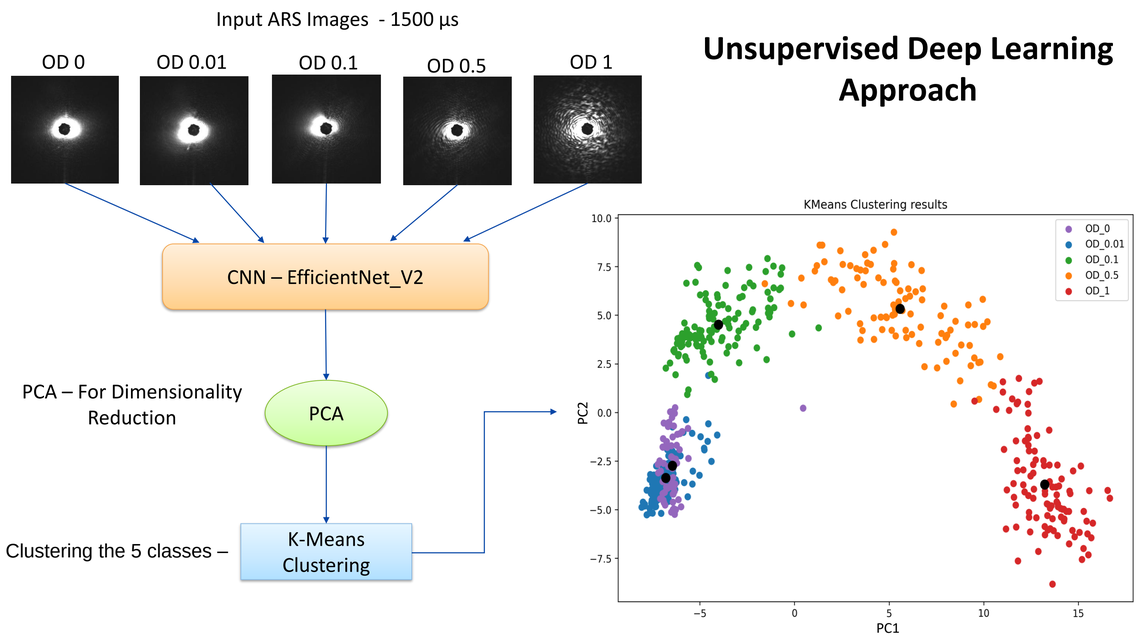


Empty droplet | Droplet with *S. aureus* | Droplet with *E.coli*

Workflow



Exposure-time classification

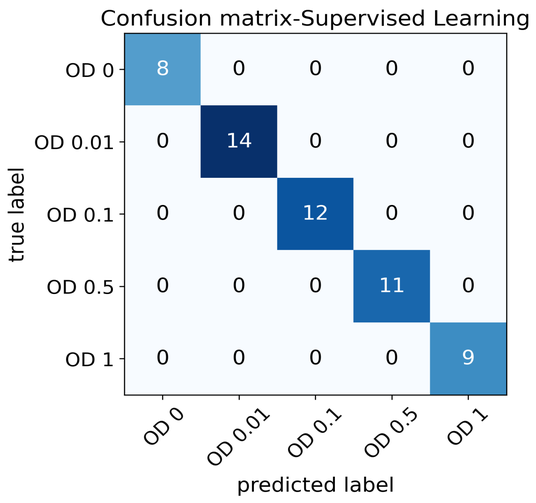


- ARS images of 5 optical densities (ODs) classes
- Convolutional Neural Network (CNN) (EfficientNet_V2) [2] to extract important features
- Dimension reduction by PCA (Principal Component Analysis)
- K-means clustering algorithm clusters the images based on the similarity of features, into 5 classes
- The same steps are repeated for 2000 µs and 4000 µs images
- All scatter plots show very similar results for all exposure times

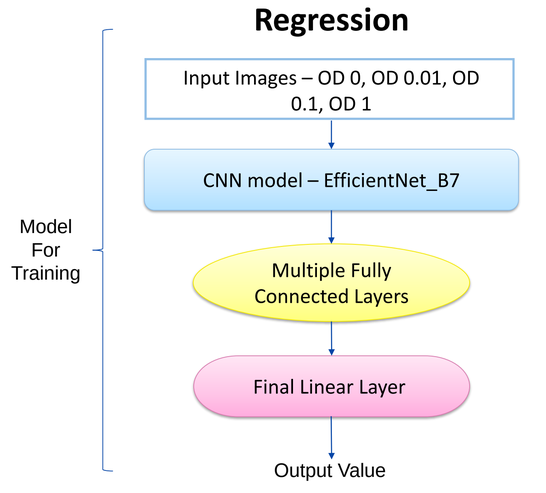
Conclusion – 1500 µs images can be used for further analysis. Results from supervised learning confirms this inference

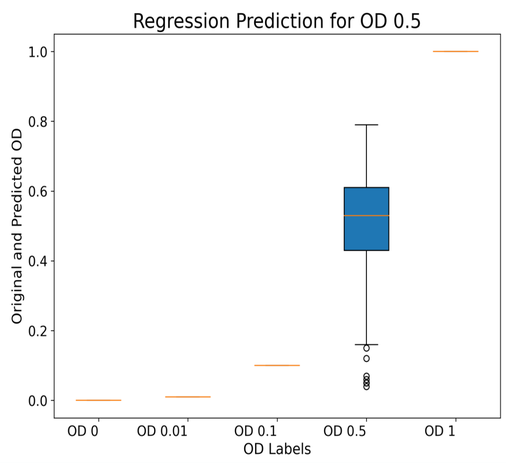
Supervised Deep Learning Approach

- CNN trained on 1500 µs ARS images
- CNN algorithm used – EfficientNet_B7 [3]
- The trained algorithm classifies all the test images correctly



Regression



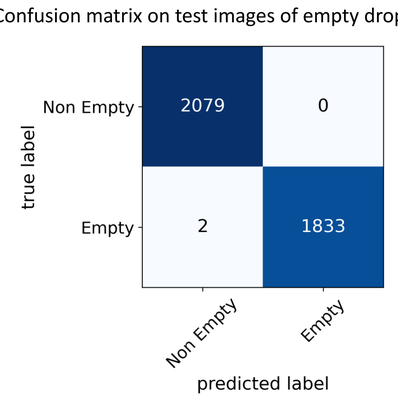


Empty droplet removal and growth analysis

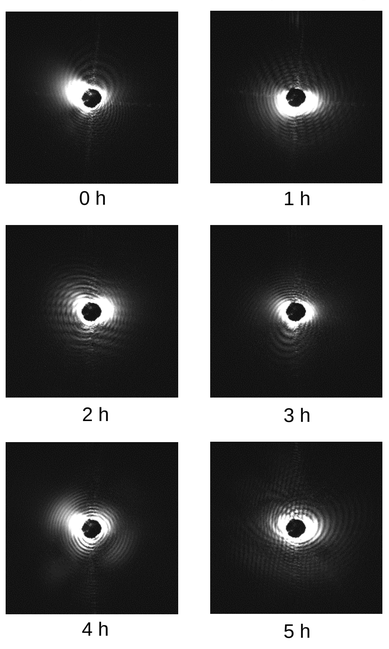
Empty droplet classification

- In the growth analysis (1500 µs) dataset many images are empty
- Important to remove these images before training a model
- Empty and non-empty droplet images collected
- CNN (EfficientNet) [3] trained to classify empty droplets

Confusion matrix on test images of empty droplet classifier

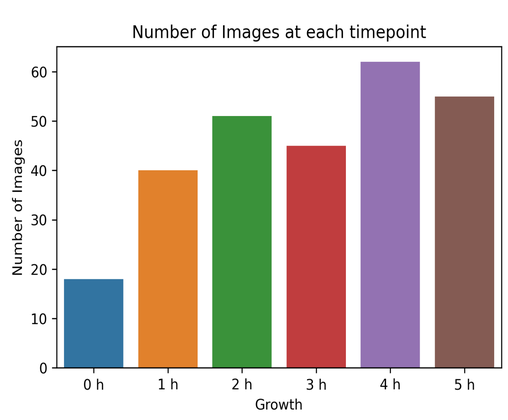


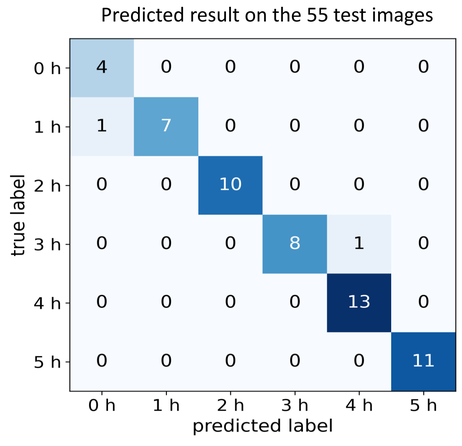
ARS images of droplets at different timepoints for growth analysis



Removing empty droplets from growth analysis dataset

- Empty droplet classifier removes all the images with empty droplets from the dataset
- Predicted – 85% of the dataset was empty
- **Classification** - Only non-empty droplets used to train a CNN (EfficientNet) [3]
- Images across 6 timepoints (0h to 5h) used for training





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References

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[2] Tan, M., & Le, Q. 2021. *ArXiv, abs/2104.00298*.
[3] Tan, M., & Le, Q. 2019. *ArXiv, abs/1905.11946*.

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