Computer Vision Enabled Dropwise Condensation Heat Transfer Measurement

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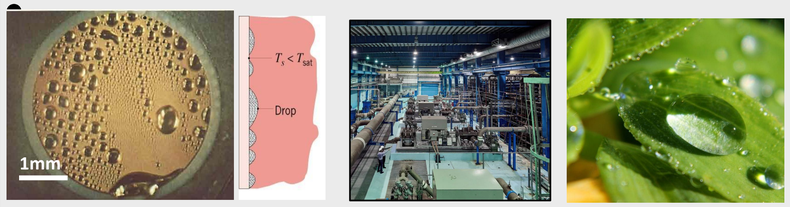
Abstract and introduction

- Condensation occurs mainly through two methods - filmwise and dropwise.
- Dropwise condensation - Surface covered by droplets which coalesce, grow to a certain size and then slip away from the surface.
- Heat transfer rate for dropwise condensation (water) is 5-7x higher than that of filmwise condensation



- We conducted a comparative study of Computer Vision and Deep Learning as methods to detect and track droplets in quantifying dropwise condensation.
- The project focused on calculating the overall heat flux value purely using computational methods.

Learnings from the project

- **Object Detection and Localization:** YOLOv8's ability to perform object detection and localization proved beneficial for identifying heat transfer images. We trained different variations of YOLOv8 like small, nano-scale, and medium version.
- **Accuracy and Precision:** The model's performance in terms of accuracy and precision was critical for reliable heat transfer calculations. Other that YOLO we also tried using ResNet and Faster RCNN Architectures.
- **Preprocessing and Data Augmentation:** YOLOv8 model required adequate preprocessing of the data and potential augmentation to ensure the model was robust.

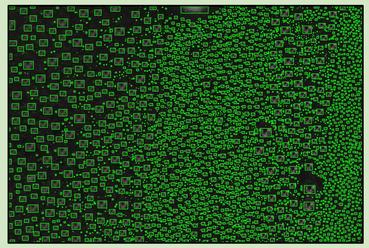
Objectives

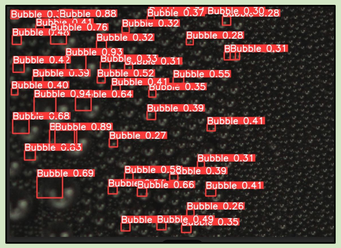
Our main objective is to estimate the condensation heat transfer performance of droplets on various types of surfaces.
To achieve this, we need to:

- Detect the presence of droplets on surface
- Track the movements and change in radius for each droplet
- Determine the radii and its growth rate for each droplet
- Calculate individual droplet's heat transfer to eventually get the total heat flux for that surface.

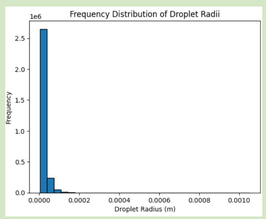
Results & Discussion

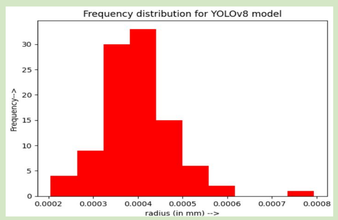
- Compared the detection results using 2 methods -
  - CV Algorithm - Using patchwise segmentation
  - YOLOv8 - Deep learning model





- As observed, the detection is done more accurately in the CV method as compared to the deep learning model.
- The below frequency distributions can help visualize the trends -





- Measuring heat flux using results from the CV method :
  - First consider the heat transfer rate as
    $Q = \varrho * L * 4 * r^2 * (dr/dt)$
  - Multiplying it with the corresponding population density gives us the corresponding heat flux value.
  - Got overall heat flux by integrating over the entire radius range.
- Considering the approximations that we did, the overall heat flux value came out to be **2178.27 W/m^2**.

Completed Tasks

- Heat Flux calculations -
  - Using the data collected from the detections and tracking using Computer Vision
- Training YOLOv8 model
- Predicting the droplet positions in the untrained images of the same dataset
- Getting the frequency distribution of the droplets detected by the YOLOv8 model.

Future Scope of Work

- Optimizing the deep learning YOLOv8 model, so as to increase the accuracy of the model.
- Explore alternate object detection models fo training such as Retinanet, Faster R-CNN, etc.
- Clearer images in the dataset would help the models to detect the droplets better.
- Once model can detect the droplets accurately with better confidence score, we can move on to tracking the droplet growth during the process using YOLOv8.
- From the droplet growth, we can calculate the overall heat flux for the given surface.

Acknowledgement & References

- https://www.researchgate.net/publication/354839026_A_Deep_Learning_Perspective_on_Dropwise_Condensation
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