Spray macroscopic parameters estimation using deep learning

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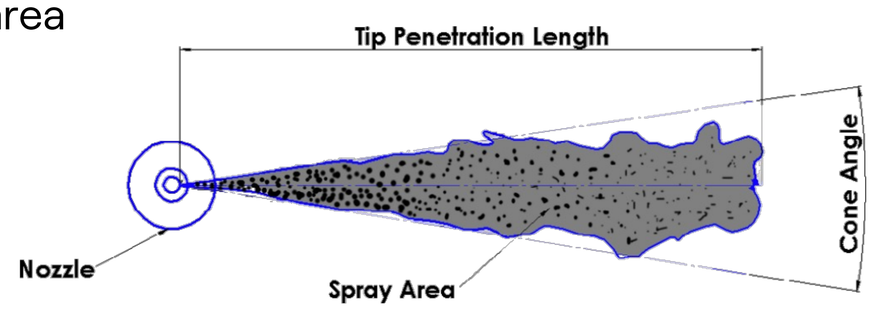
1. Introduction

- Injection strategies contribute greatly to engine efficiency, combustion process, and pollution
- To decrease pollution and emission and increase efficiency, spray macroscopic parameters need to be determined
- 3 main parameters - cone angle, penetration length, spray area



2. Data

- Obtained by injecting diesel fuel into a constant volume chamber filled with nitrogen at 22 Celsius
- 512x256 in RGB format by Photron SA1.1 high-speed camera
- A subset of 200 collected images used
- Segmentation labels were collected by four experts

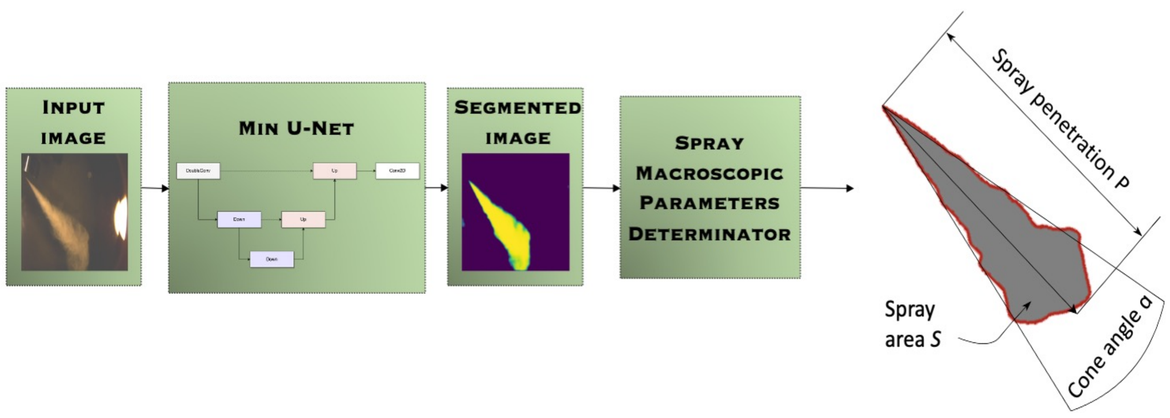
4. Methodology

- An input image is firstly segmented with a lightweight neural network based on U-Net, called Min U-Net
- After that PCA is used to obtain right-hand side orientation
- Macroscopic parameters are estimated from the oriented image and error is calculated

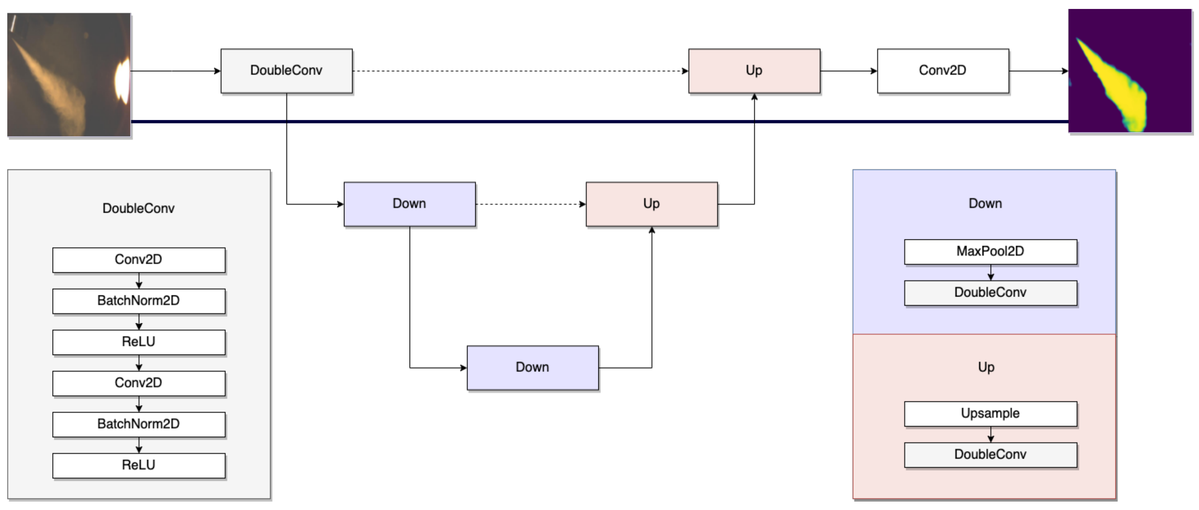
Algorithm 1 Estimation of Macroscopic Spray Parameters

Require: Input image

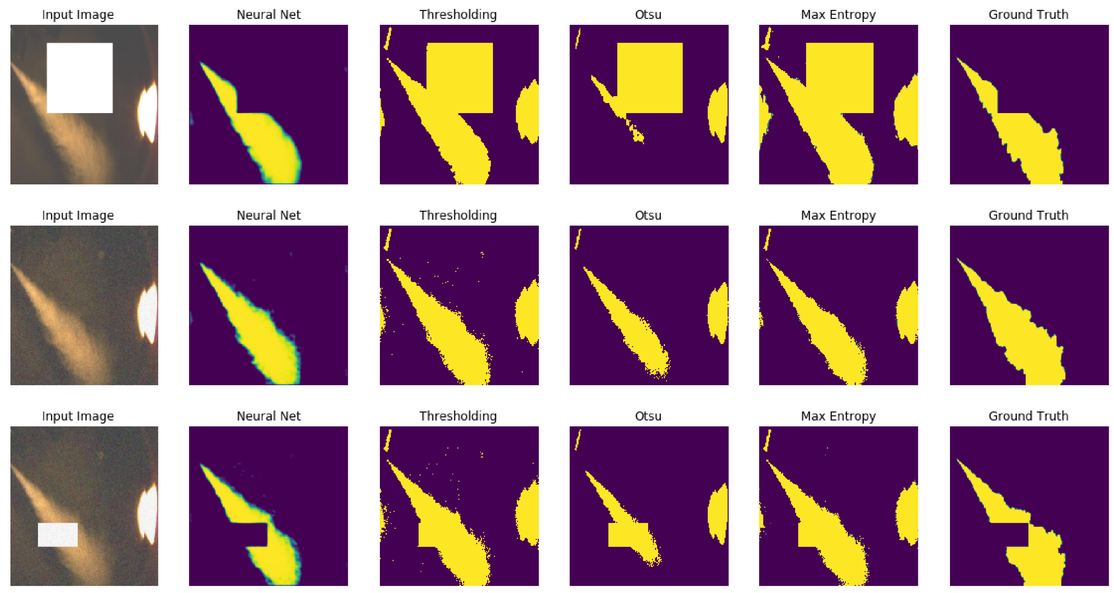
$model \leftarrow MinUNet()$
$input\_image \leftarrow PreprocessImage(input\_image)$
$output\_image \leftarrow model(input\_image)$
$orientation\_angle \leftarrow PCA(output\_image)$
$rotated\_output\_image \leftarrow RotateImage(output\_image, orientation\_angle)$
$macroscopic\_parameters \leftarrow DetermineParameters(rotated\_output\_image)$
return $macroscopic\_parameters$



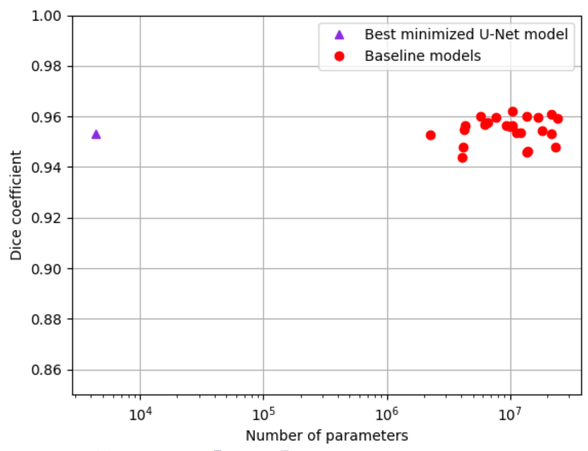
4. Min U-Net architecture



6. Results



- Min U-Net achieves a mean dice score of 0.95
- It only has 4.4K parameters
- It achieves 11.94 ms/image – more than two times faster than the fastest compared SOTA baseline model
- Cone angle with a mean average error of 1.08 degrees
- Spray penetration and spray area with a mean relative error of 5.95% and 4.05%



	Cone angle MAE	Spray penetration MRE (%)	Spray area MRE (%)
Thresholding	2.36	25.55	14.36
Otsu	9.05	41.84	52.51
Max Entropy	2.68	26.47	18.05
Min U-Net	**1.08**	**5.95**	**4.05**

7. Conclusion

Spray macroscopic parameters are essential contributors to engine efficiency and emissions. To determine them, a lightweight neural network called Min U-Net was used. It achieves state-of-the-art segmentation results while being 2x faster and around 500 times smaller than other baseline models. It also outperforms traditional methods.

8. Project Acknowledgement

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