RRLAB
THE ROBOTICS RESEARCH LAB

Object Detection under Image Noises for Agricultural Use-Cases

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Outline

- Perception systems of agricultural vehicles
- Noise models and denoising techniques
- Object detection and evaluation metrics
- Experiments and results

Agricultural Perception Systems - Hardware

- Agriculture has heavy duty vehicles and cameras
- Wireless transmission due to size
- Often uses analog transmission techniques
  - Mechanically stable
  - More image noise

https://www.motec-cameras.com/en/industries/agricultural-vehicles

Agricultural Perception Systems - Task

- Depending on goal different perception tasks
- Surveillance
  - Fruit yield
  - Soil state
  - Plant health
  - …
- Automation
  - Position of Fruits
  - Leaves
  - Rows
  - Obstacles/Persons
  - …

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Noise Models - I

Gaussian Noise

Salt&Pepper Noise

Speckle Noise

Uniform Noise

Brownian Noise

Gamma Noise

Noise Models - II

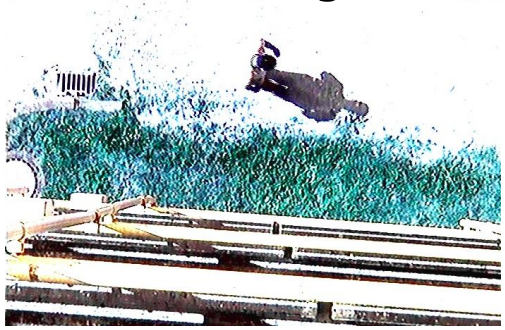
Rayleigh Noise

Periodic Noise

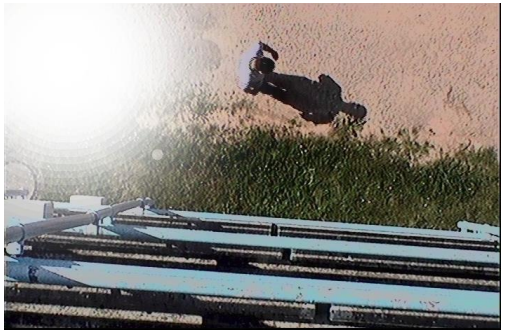
Poisson Noise

Color Quantization

Enhanced Brightness



Bloom Effect

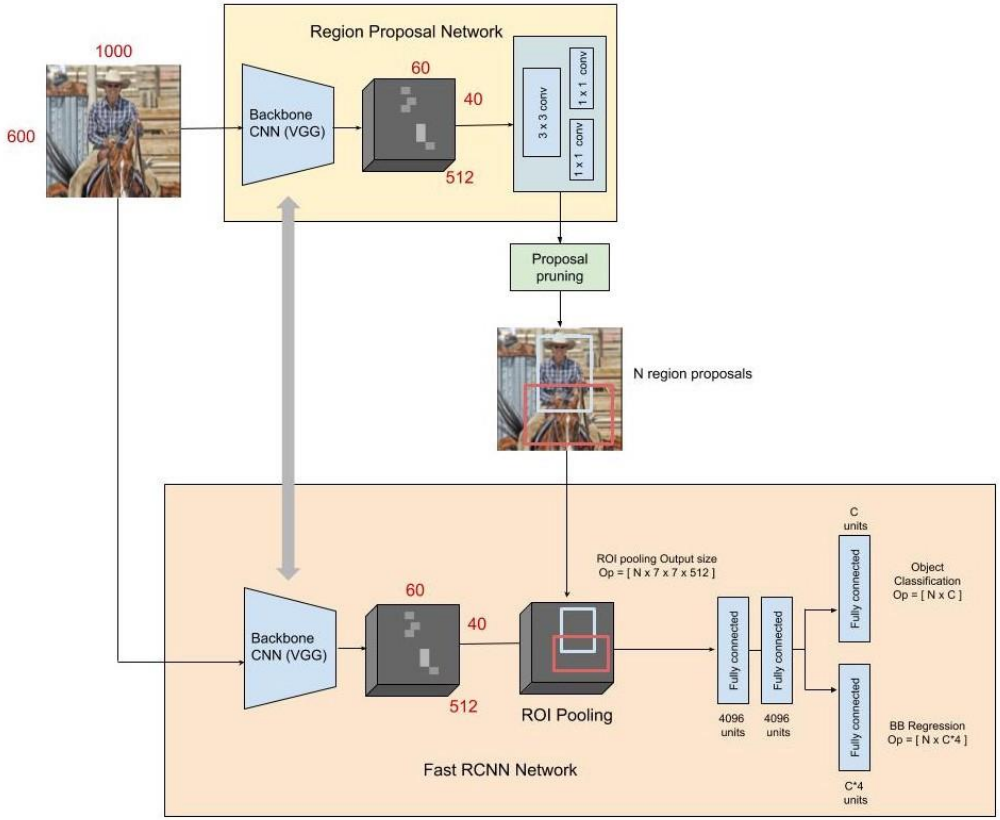


Denoising Techniques

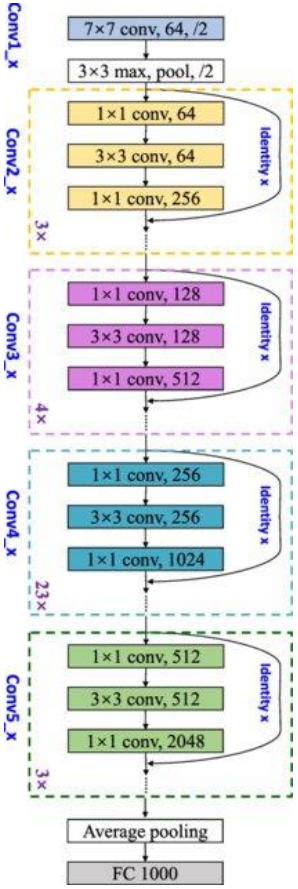
- Mean Filter
- Median Filter
- Gaussian Blur
- Bilateral Filter
- Wavelet Filter

- Three variance values for noise models:
  Low, Medium, High

Object Detection Network



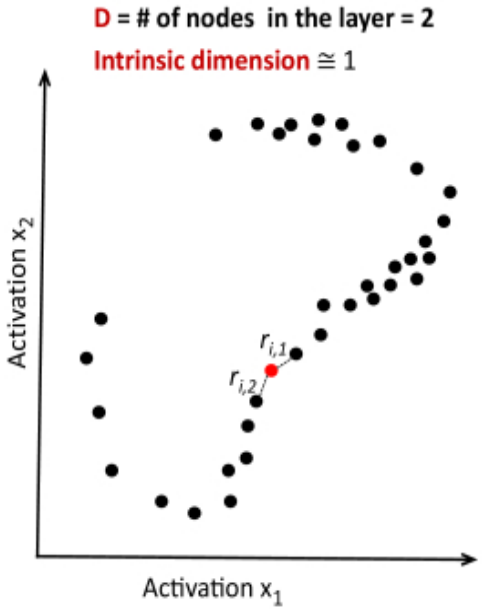
Faster R-CNN



ResNet-101

Evaluation Metrics

- Mean Average Precision (mAP)
- Peak Signal to Noise Ration (PSNR)
- Intrinsic Dimension (ID)
  - Two Nearest Neighbor estimator (TwoNN)[2]
    - Ratio between first and second nearest neighbor of each data point
    - Weak assumption: density is constant on the scale of the distance between each point and its second neighbor



1) For each data point *i* compute the distance to its first and second neighbour ($r_{i,1}$ and $r_{i,2}$)

2) For each *i* compute $\mu_i = \frac{r_{i,2}}{r_{i,1}}$

The probability distribution

$$P(\mu) = \frac{d}{\mu^{1+d}}$$

where d is the ID, independently on the local density of points.
3) Infer d from the empirical probability distribution

4) Repeat the calculation selecting a fraction of points at random. This gives the ID as a function of the scale.

Experiments - Overview

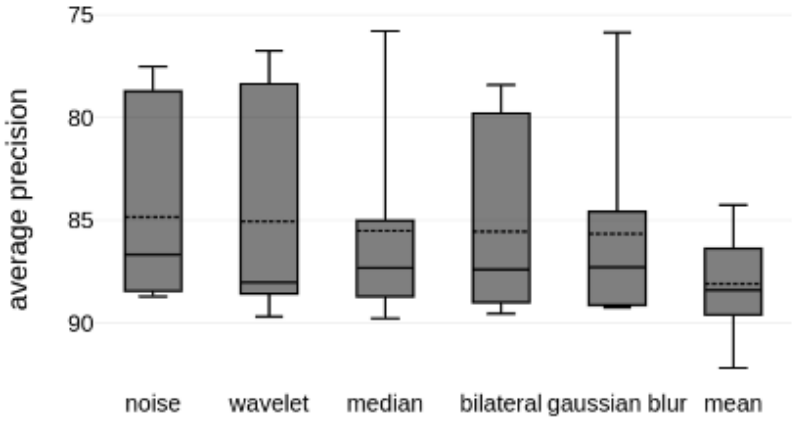
- Baseline without additional noise
- Noise level via PSNR
- Single noise: low, medium, high variance
  - Without Filter
  - With Filter
- Mixture of noises
  - With Filter
  - Without Filter

	AP@0.5	mAP@[0.05,0.95]
Baseline	91.67	41.4

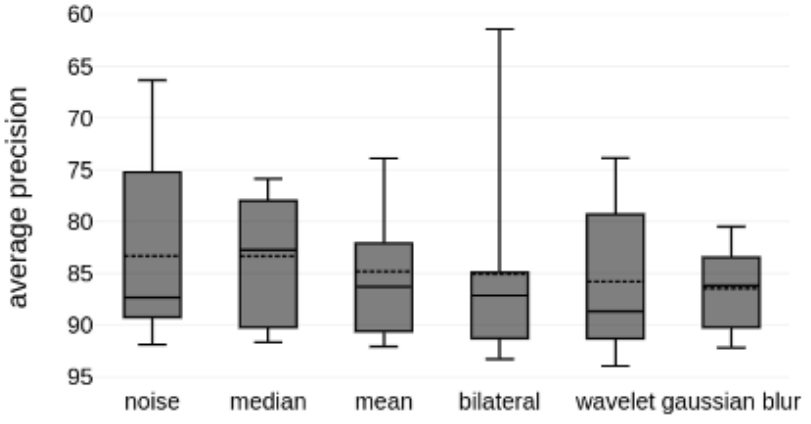
Experiments – PSNR Noise

Noise Level	Gaus-sian	Salt& Pepper	Speckle	Uni-form	Gamma	Ray-leigh	Color Quanti-zation
Low	11.78	11.70	12.15	18.88	17.83	16.60	28.33
Medium	6.78	8.69	10.73	8.81	11.83	10.14	27.75
High	6.13	5.69	9.70	8.30	8.56	8.03	22.02
De-noising on Low							
Blur	18.35	13.37	19.46	19.37	19.50	17.75	26.62
Mean	18.58	18.06	19.73	19.07	19.22	17.58	25.05
Median	17.66	24.46	17.28	19.22	19.93	17.84	25.83
Bilateral	11.80	11.73	12.17	19.32	18.22	16.90	28.70
Wavelet	18.45	17.55	14.54	19.47	19.35	17.63	27.33

Experiments – Low Noise

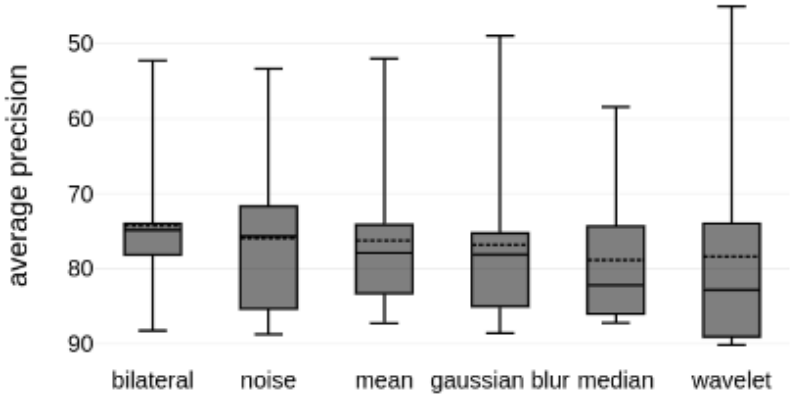


Infer on noisy and denoised images

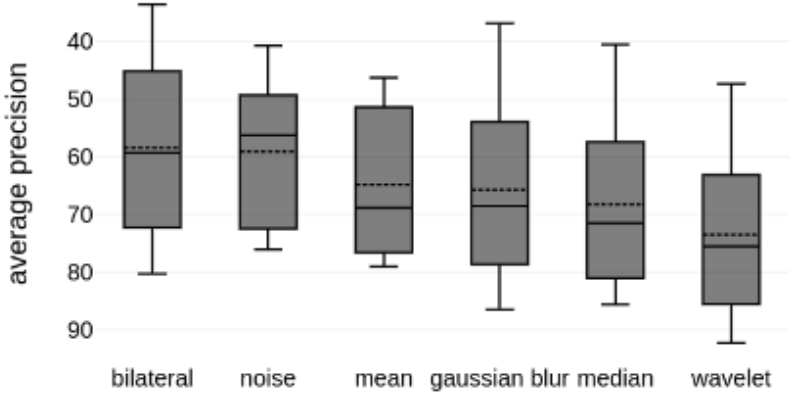


Infer on original images

Experiments – Medium Noise

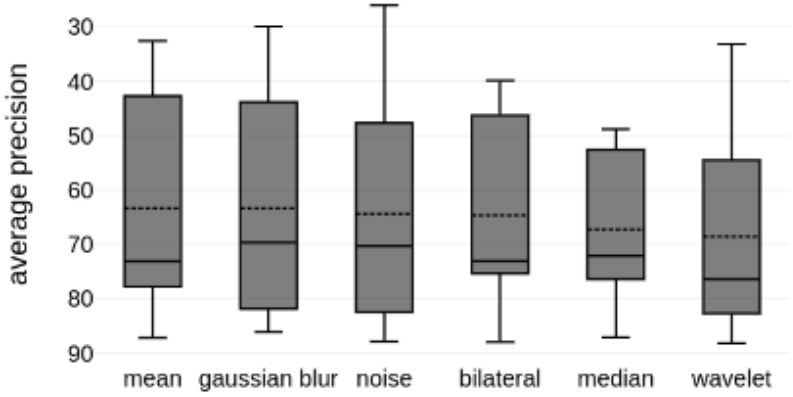


Infer on noisy and denoised images

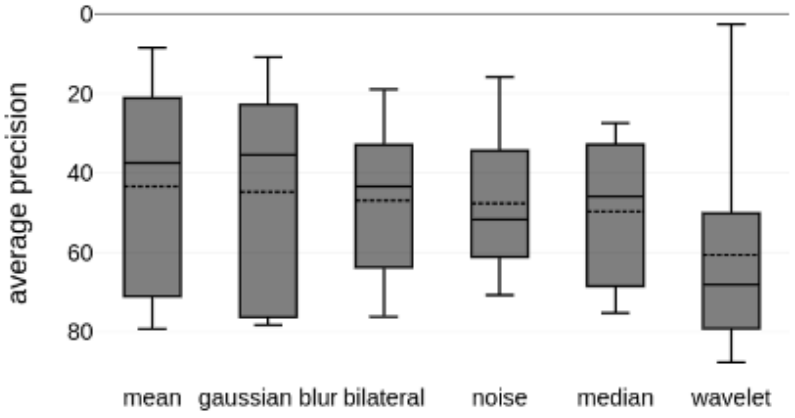


Infer on original images

Experiments – High Noise

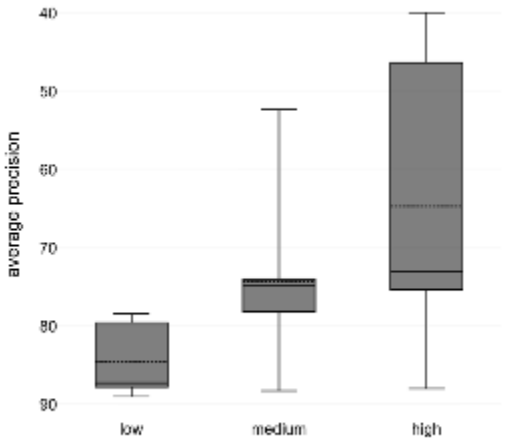


Infer on noisy and denoised images

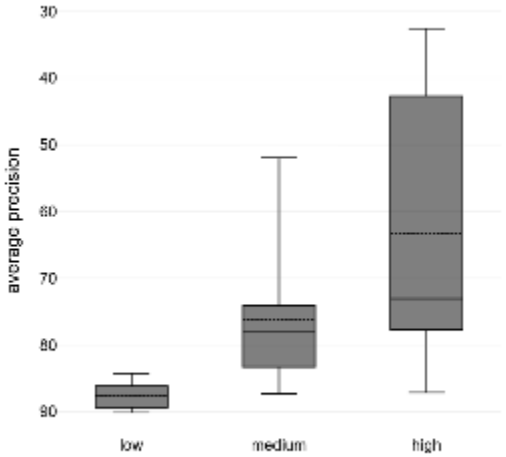


Infer on original images

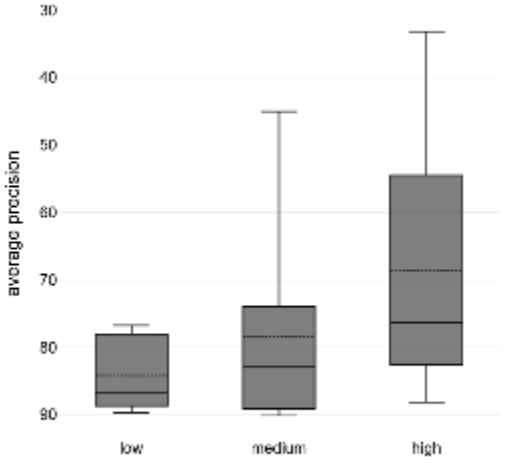
Experiments – Mixture (Excerpt)



Bilateral filter

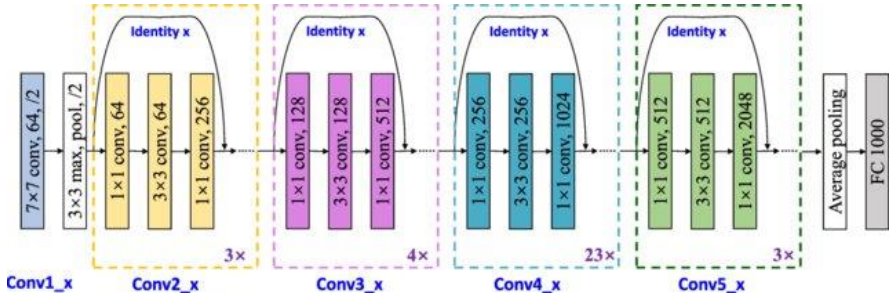


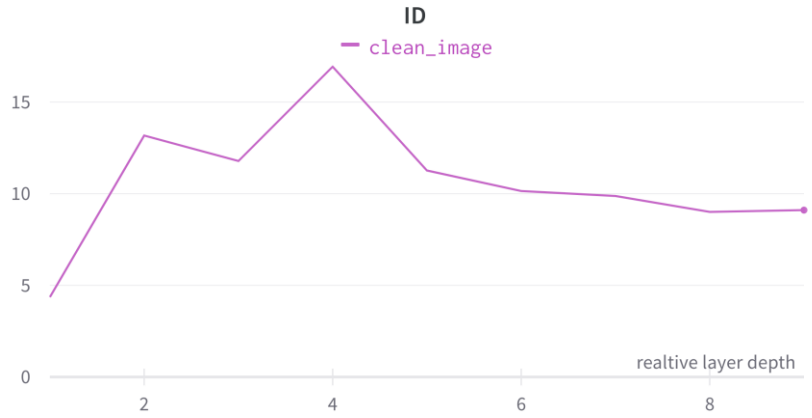
Mean filter



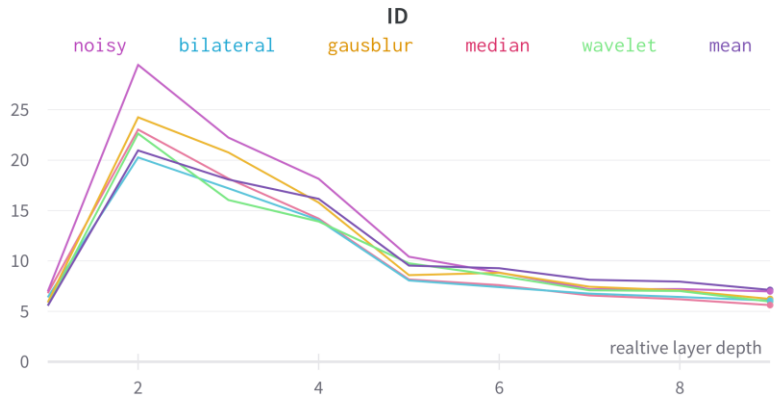
Wavelet filter

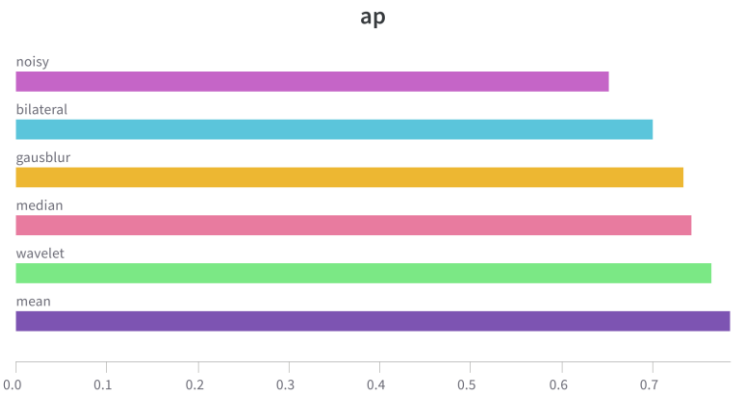
Experiments – ID without Noise



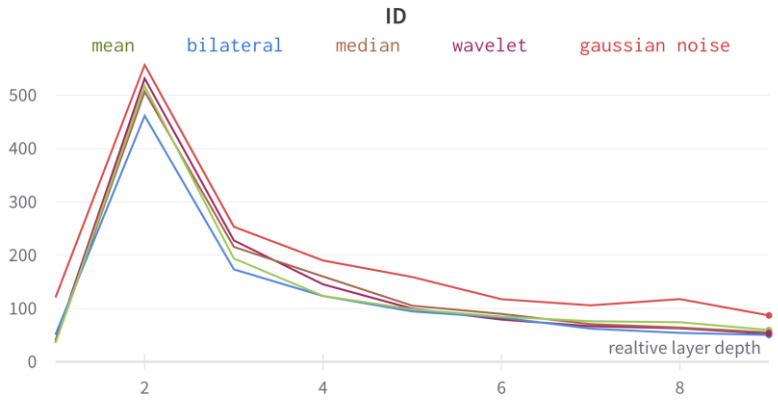


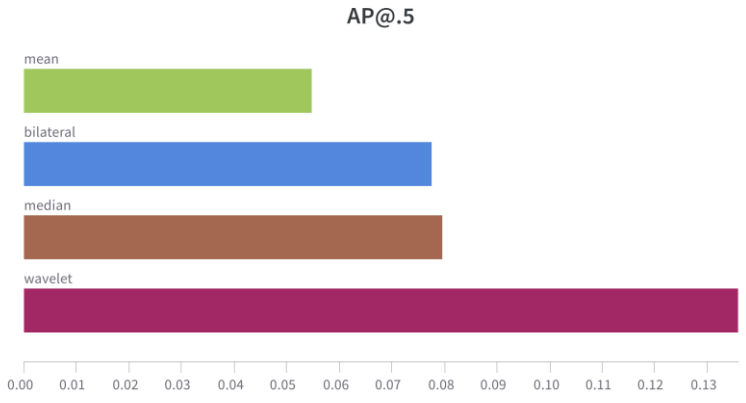
Experiments – ID with Noise





Experiments – ID train w/o Noise eval with





Conclusion

- Low level noise minimum impact on the detection
- Increasing noise level degrades object detection accuracy significantly
- Denoising methods remove noise and promote detection accuracy
- Wavelet denoising generalizes better for different kinds of noise with varying intensities
- Denoised images better generalization characteristics
- Denoised images require less parameters to describe data representation on object manifold