Blind Denoising of Mixed Gaussian-Impulse Noise by Single CNN

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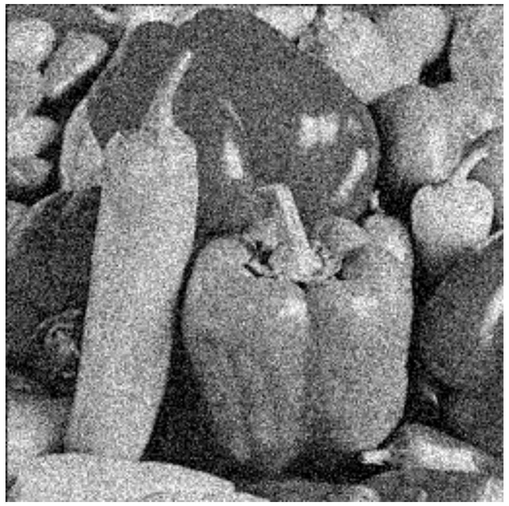
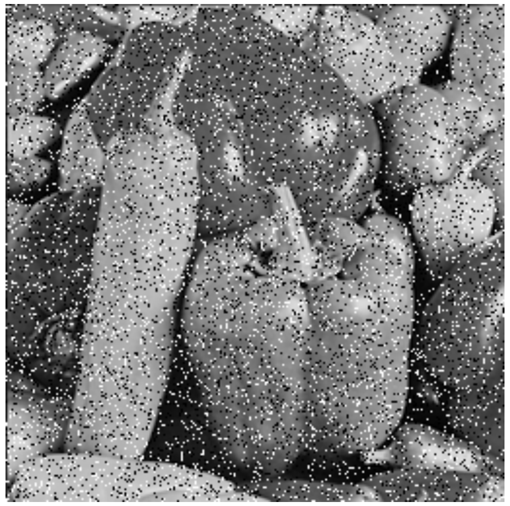
Introduction

- We propose a mixed noise removal method.

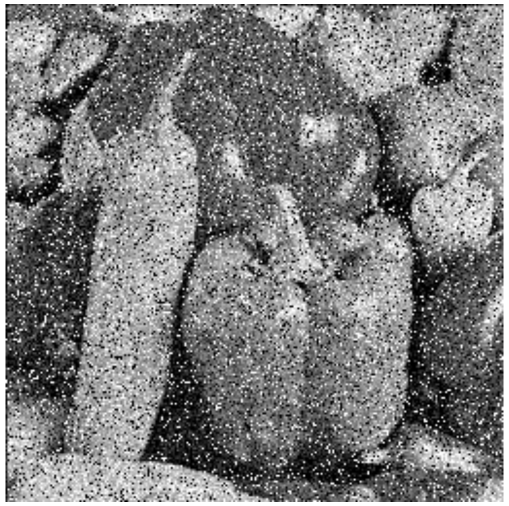
  The mixture of Additive White Gaussian Noise (AWGN) and Impulse Noise (IN) is considered.



Additive White Gaussian Noise



Random Value Impulse Noise



AWGN-RVIN mixed noise

- Our proposed method is based on CNN.

Type of noise

- Additive White Gaussian Noise (AWGN)

$$y_G(i,j) = x(i,j) + n_G(i,j)$$

➡ Caused by thermal motion in camera sensors

- Random Valued Impulse Noise (RVIN)
- Salt-and-Pepper Impulse Noise (SPIN)

$y_I(i,j) = n_I(i,j)$ with probability $p\ (RVIN), s\ (SPIN)$

➡ Caused by transmission error

Mixed noise

◎ Generally, it is rare that only one type of noise is added.

↓

Mixed noise composed of AWGN and IN is considered.

$$y(i,j) = \begin{cases} n_{RVIN}(i,j) & with\ probability\ \ p \\ n_{SPIN}(i,j) & with\ probability\ \ s \\ x(i,j) + n_{AWGN}(i,j) & with\ probability\ 1-p-s \end{cases}$$

$y(i,j)$: noisy pixel $x(i,j)$: noise-free pixel

$n_{RVIN}(i,j)$: Random Valued Impulse noise (RVIN)

$n_{SPIN}(i,j)$: Salt and Pepper Impulse noise (SPIN)

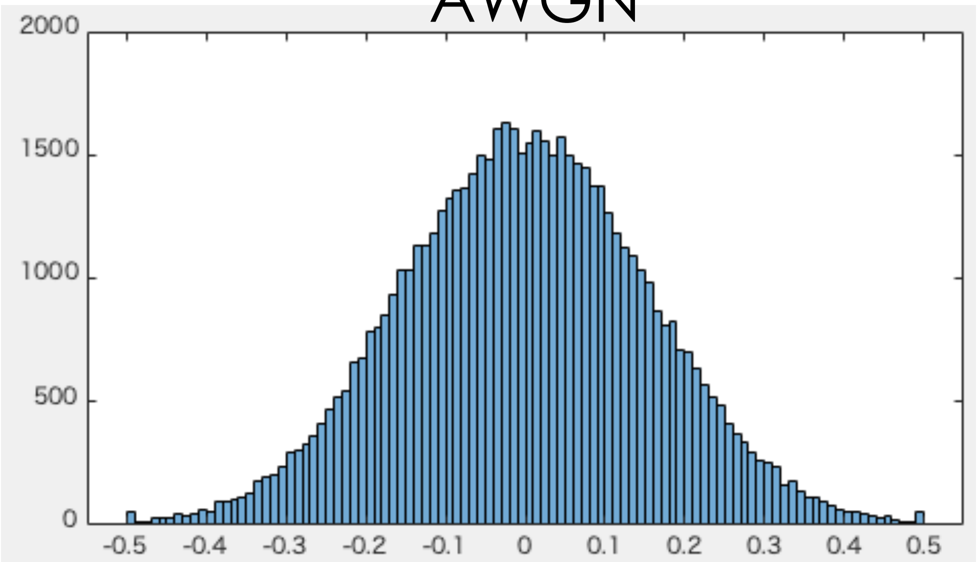
$n_G(i,j)$: Additive White Gaussian noise (AWGN)

Mixed noise

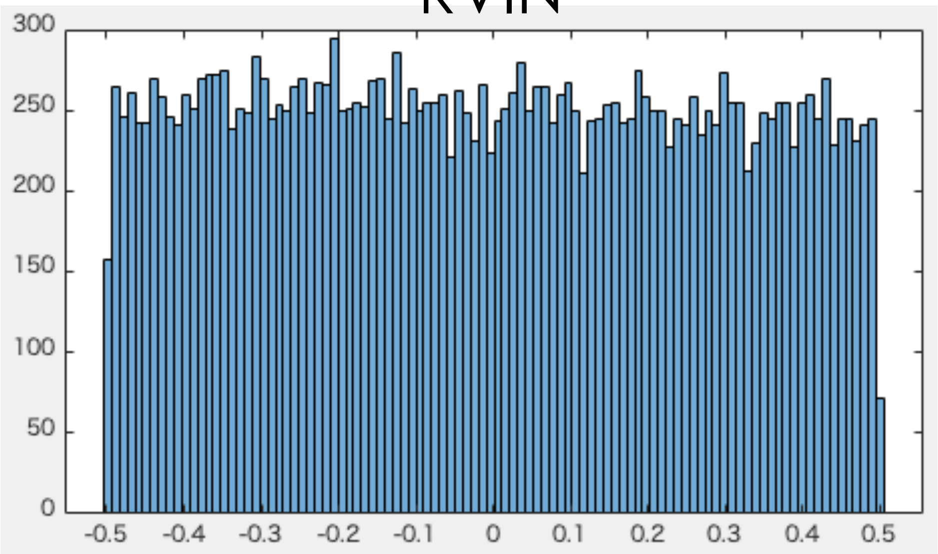
◎ Mixed noise removal is more difficult than single noise removal.

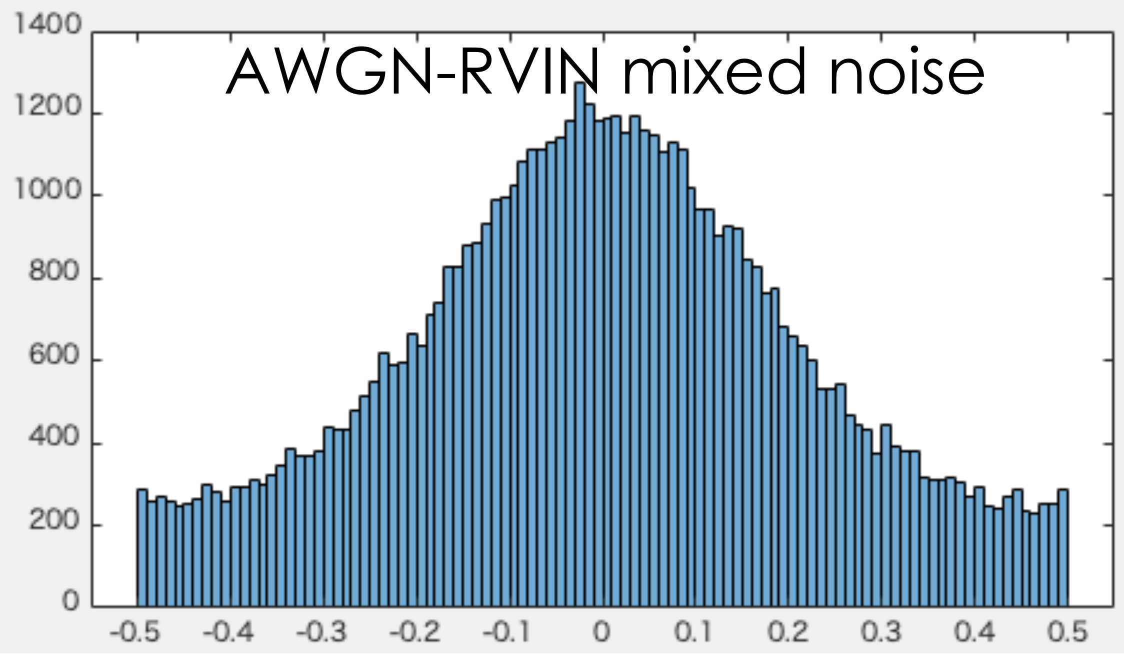
→ Because the noise distribution model is complicated

AWGN



RVIN



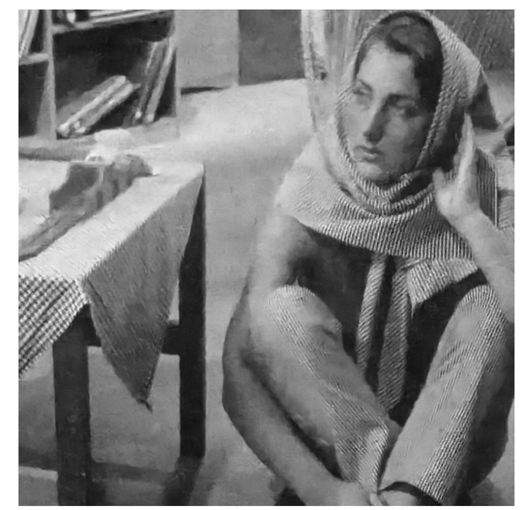


Mixed noise

- Denoising method for single noise removal cannot remove mixed noise effectively.

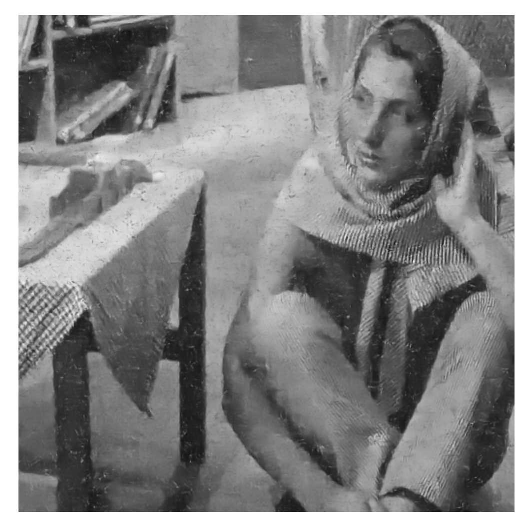
DnCNN

Single noise
$\sigma = 30$ (AWGN)



26.05 dB

Mixed noise
$\sigma = 30$ (AWGN)
$p = 10$ (RVIN)



23.75 dB

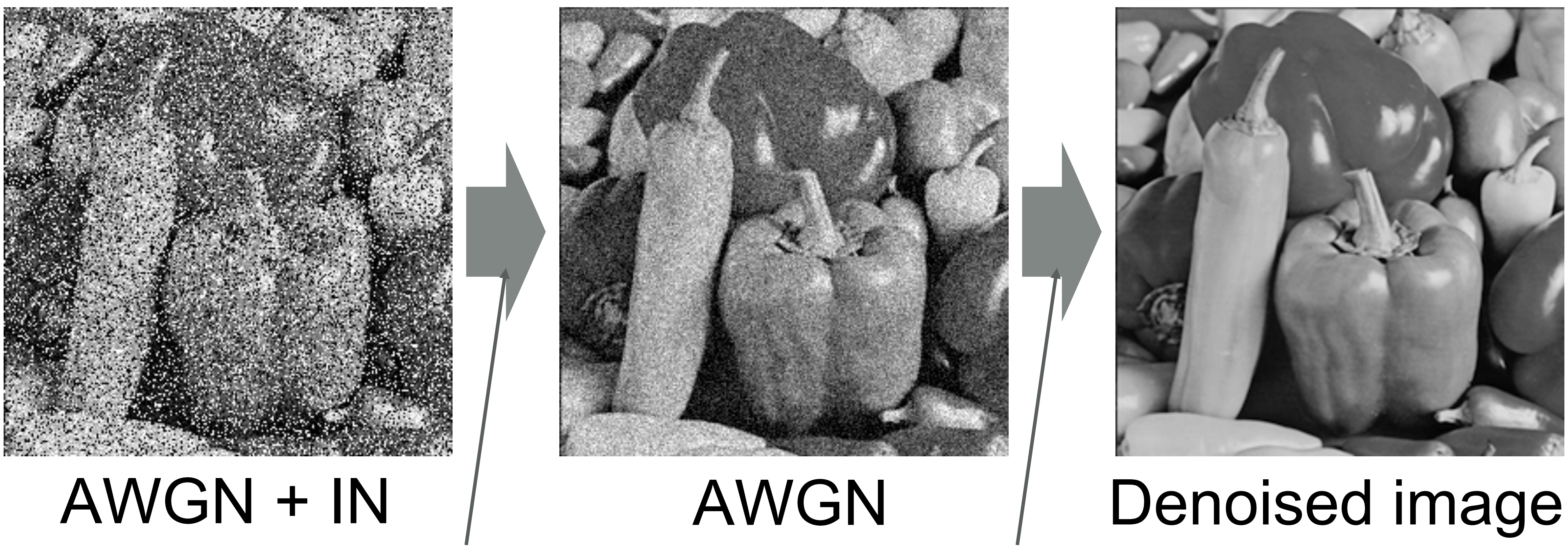
Noisy image

Denoised image

Problem

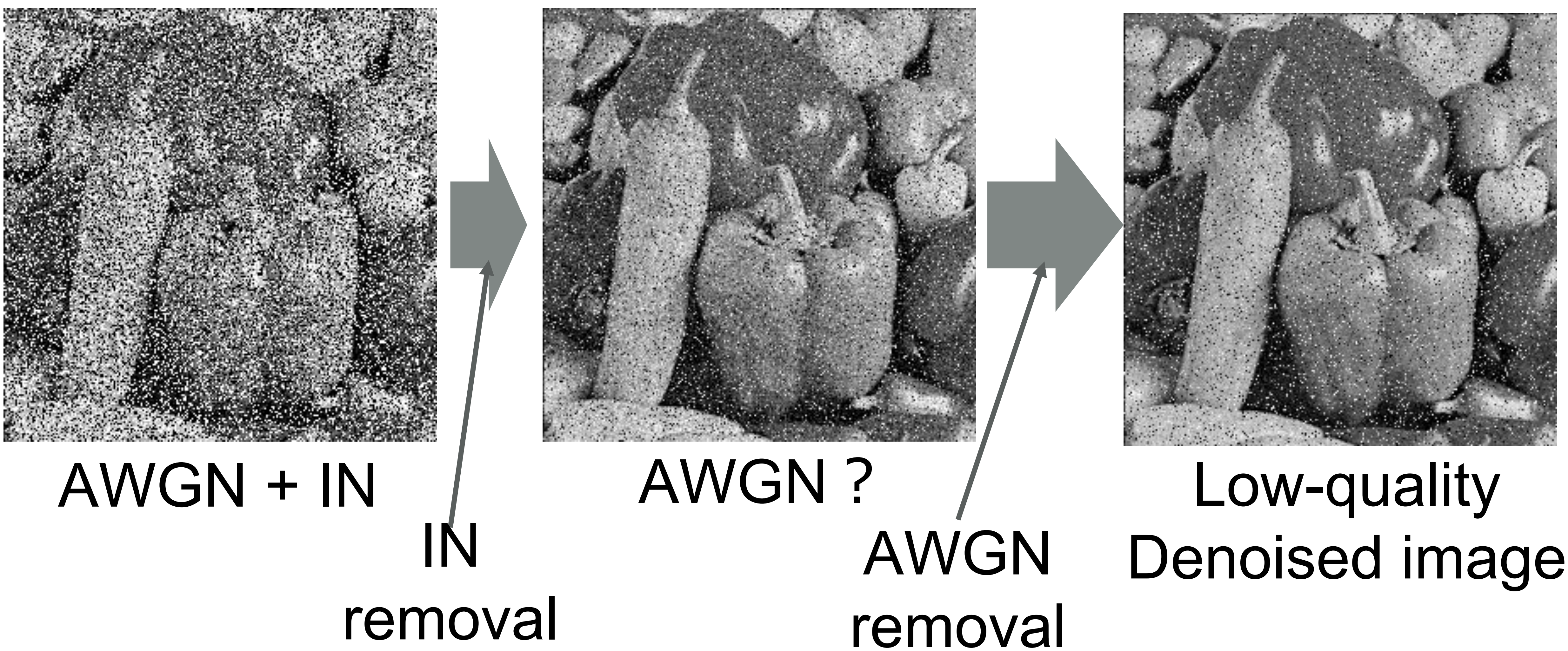
◎In the conventional methods, noise removal is performed according to the distribution of noise.

→Remove AWGN after removing RVIN & SPIN



Problem

IN detection & removal becomes difficult when the noise level is high.
→ If the IN removal does not work well, subsequent AWGN removal will be adversely affected.



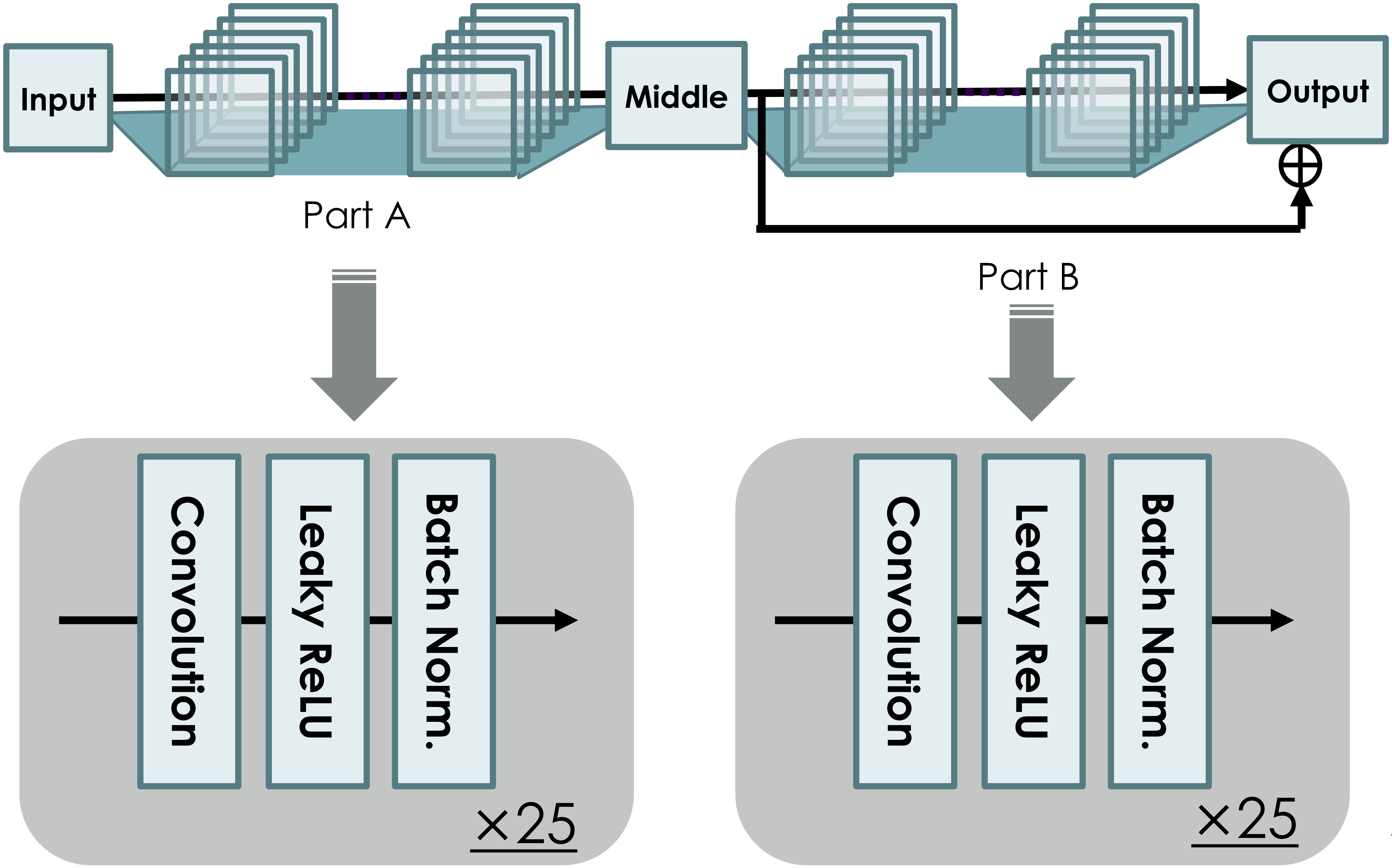
Proposed method

Our method
→ All denoise processing is performed in a single CNN.

Feature of our method

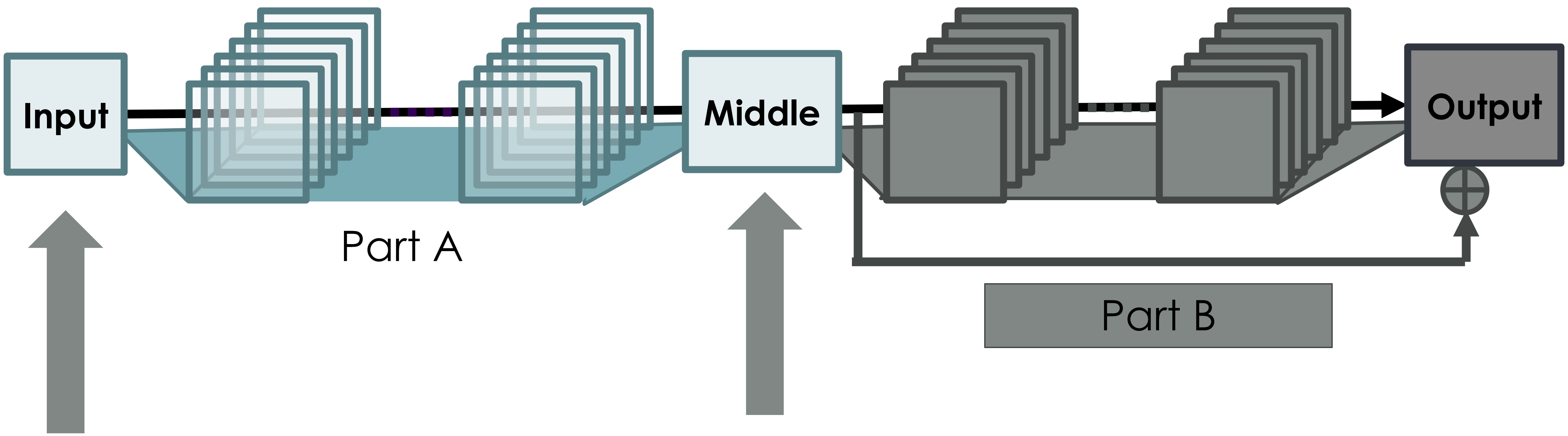
・Blind denoising
・Does not require pre-processing such as IN removal.
・Execution time is short compared to high-precision methods

CNN architecture



Training

① First step

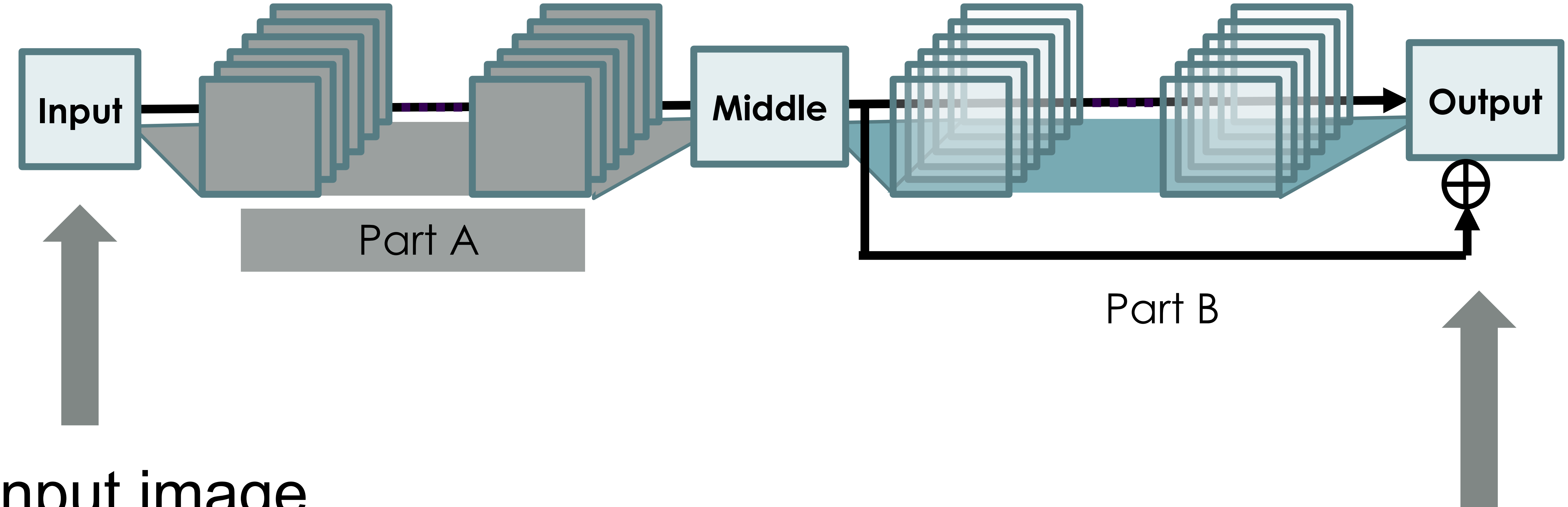


Input image corrupted by AWGN + IN

Train to be a AWGN-only image

Training

② Second step



Input image corrupted by AWGN + IN

Train to be a noise-free image

Dataset

Microsoft COCO dataset is used for training.

The training image is corrupted by

σ = [0,10,20,30,40,50] ←AWGN

p = [0,5,10,15,20,25,30,35,40,45] ←RVIN

s = [0 ~ 40] ←SPIN

→ By training with various noise levels, noise can be removed even if the noise level is not known (Blind denoising)

Training parameters

- 6000 training images
- Patch size: 33x33
- Batch size: 256
- Solver: Adam
- Initial learning rate: 0.00001
- Epoch: 10 (About 140000 iterations)

- About 30 hours to train with our MATLAB implementation on single GeForce GTX 1080Ti.

Conventional methods

[1] Tao Chen and Hong Ren Wu, “Adaptive impulse detection using center-weighted median filters,” IEEE Signal Processing Letters, vol. 8, no. 1, pp. 1–3, 2001.

[2] Kostadin Dabov, Alessandro Foi, Vladimir Katkovnik, and Karen Egiazarian, “Image denoising by sparse 3-d transform- domain collaborative filtering,” IEEE Transactions on image processing, vol. 16, no. 8, pp. 2080–2095, 2007.

[3] L. Liu, L. Chen, C. P. Chen, Y. Y. Tang *et al.*, “Weighted joint sparse representation for removing mixed noise in image,” *IEEE transactions on cybernetics*, vol. 47, no. 3, pp. 600–611, 2017

[4] M.T. Islam, S.M. Rahman, M.O. Ahmad, and M. Swamy, “Mixed gaussian-impulse noise reduction from images using convolutional neural network,” Signal Processing: Image Communication, vol.68, pp.26–41, 2018.

Comparison

Mixed noise
$\sigma = 15$
$p = 15,30,45$
$s = 0$

Image	p	Method			
		AWCMF + BM3D	(ACWMF +) WSR	(ACWMF +) Islam's	Ours
Lena	15%	32.41	32.06	32.28	**32.56**
	30%	30.25	30.27	29.10	**31.71**
	45%	26.65	28.09	24.87	**30.36**
Barbara	15%	26.70	27.60	25.67	**29.43**
	30%	24.79	25.63	24.17	**28.32**
	45%	22.59	22.79	21.67	**26.25**
Bridge	15%	**29.60**	29.51	28.86	29.16
	30%	27.16	27.67	26.54	**28.09**
	45%	24.02	22.44	22.86	**26.53**
Boat	15%	29.65	29.16	29.12	**30.30**
	30%	27.55	27.72	27.02	**29.19**
	45%	24.78	25.17	23.62	**27.60**
Airplane	15%	33.42	**33.66**	32.52	32.87
	30%	30.36	31.79	28.81	**31.88**
	45%	25.51	26.73	23.32	**30.44**
Pepper	15%	34.94	**35.02**	34.07	33.49
	30%	31.60	32.26	29.90	**33.36**
	45%	26.71	28.73	24.54	**32.09**
Hill	15%	**32.51**	32.30	31.61	31.73
	30%	30.36	30.40	29.04	**30.98**
	45%	26.56	27.65	24.69	**29.86**
BSDS300	15%	27.64	27.03	27.70	**28.51**
	30%	25.76	25.78	25.29	**27.30**
	45%	22.88	23.59	22.13	**25.87**

Comparison

Mixed noise
$\sigma = 25$
$p = 15,30,45$
$s = 0$

Image	p	Method			
		AWCMF + BM3D	(ACWMF +) WSR	(ACWMF +) Islam's	Ours
Lena	15%	29.87	29.81	29.87	**30.46**
	30%	28.10	28.41	27.93	**29.79**
	45%	25.53	26.32	24.88	**28.54**
Barbara	15%	24.91	24.87	24.52	**27.28**
	30%	23.57	23.58	23.36	**26.35**
	45%	21.91	22.04	21.65	**24.75**
Bridge	15%	**26.76**	26.37	26.61	26.72
	30%	25.32	25.31	25.10	**25.97**
	45%	22.98	21.40	22.62	**24,81**
Boat	15%	27.47	27.11	27.61	**28.31**
	30%	26.01	26.09	26.08	**27.39**
	45%	23.70	24.30	23.45	**26.10**
Airplane	15%	30.44	30.62	30.34	**30.73**
	30%	28.06	28.55	28.00	**29.90**
	45%	24.31	24.51	23.97	**28.40**
Pepper	15%	31.65	**31.79**	31.65	31.76
	30%	28.95	29.84	28.70	**31.30**
	45%	25.36	26.56	24.87	**30.04**
Hill	15%	**29.70**	29.30	29.48	29.55
	30%	28.09	28.41	27.80	**28.99**
	45%	25.16	26.10	24.59	**28.01**
BSDS300	15%	25.74	25.42	25.97	**26.83**
	30%	24.35	24.34	24.42	**25.95**
	45%	22.10	22.78	21.89	**24.80**

Comparison

Mixed noise

$\sigma = 20$

$p = 10$

$s = 15$

Image	Method			
	AMF + BM3D	(AMF +) WSR	(AMF +) Islam's	Ours
Lena	30.50	30.32	30.12	**31.10**
Barbara	25.10	25.81	24.68	**28.11**
Bridge	27.46	**27.51**	27.12	27.36
Boat	27.88	27.72	27.79	**28.88**
Airplane	30.85	30.98	30.17	**31.22**
Pepper	32.62	**32.76**	31.84	32.43
Hill	**30.43**	30.24	29.83	30.10
BSDS300	26.03	25.86	25.97	**27.24**

Comparison on running time

Mixed noise
$\sigma = 15$
$p = 15$
$s = 0$

Image	Device	Method			
		AWCMF + BM3D	(ACWMF +) WSR	(ACWMF +) Islam's	Ours
256x256	CPU	0.99 s	13.1 min.	2.07 s	6.48 s
	GPU	-	-	1.06 s	0.42 s
512x512	CPU	5.05 s	49.7 min.	7.22 s	30.39 s
	GPU	-	-	3.18 s	0.80 s

Comparison

Original

Noisy σ=15, p=30

ACWMF + BM3D/24.37dB

WSR / 25.60dB

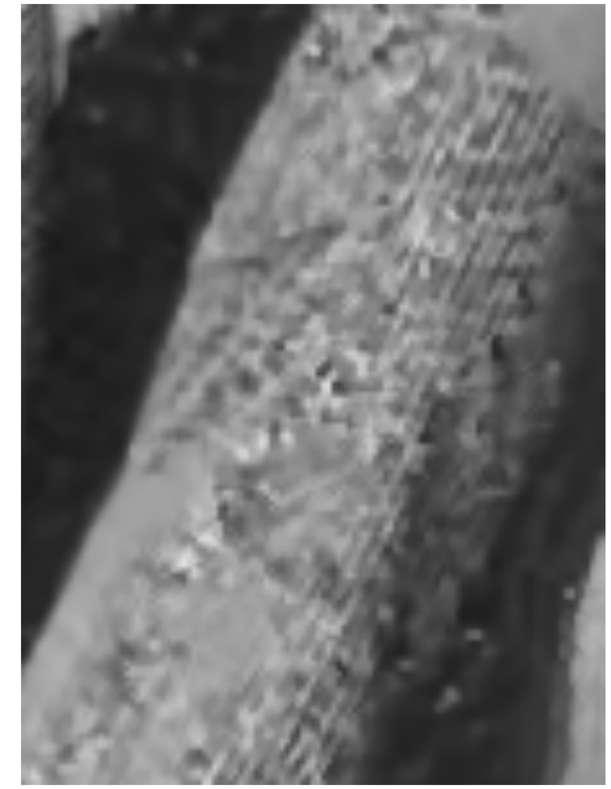
Islam's / 24.17dB

Proposed / 28.30dB

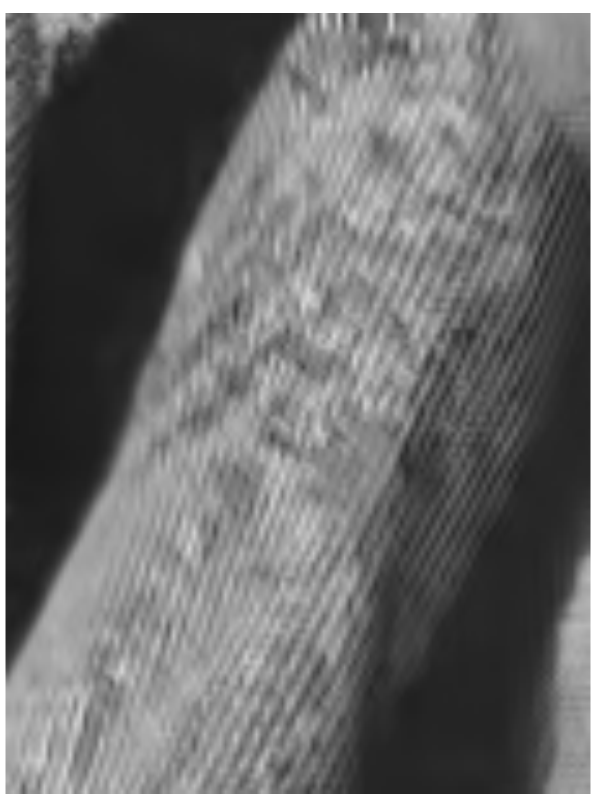
Comparison

original

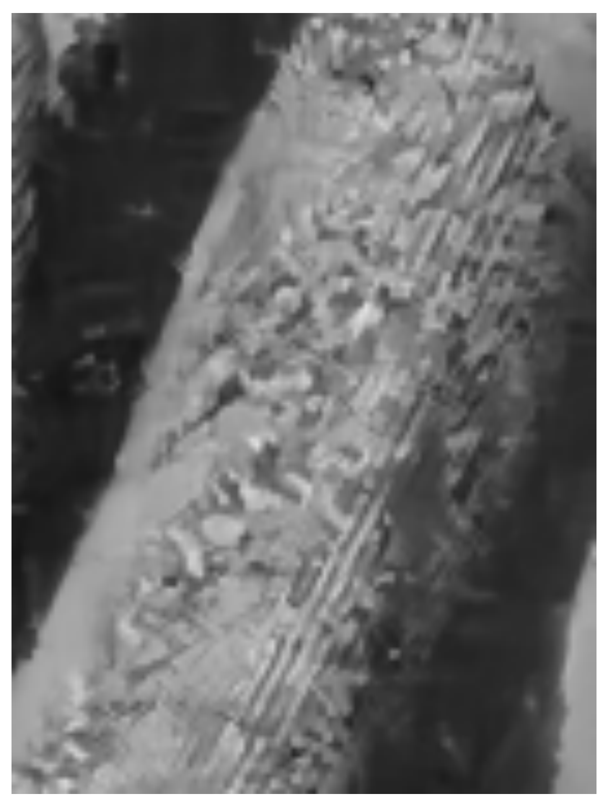
Noisy $\sigma=15$, $p=30$



ACWMF + BM3D/24.37dB



WSR / 25.60dB



Islam’s / 24.17dB

Proposed / 28.30dB

Comparison

Original

Noisy σ=20, p=10, s=15

AMF + BM3D/30.49dB

WSR / 30.31dB

Islam's / 30.12dB

Proposed / 31.09dB

Comparison

Original

Noisy σ=20, p=10, s=15

AMF + BM3D/30.49dB

WSR / 30.31dB

Islam's / 30.12dB

Proposed / 31.09dB

Training method

Mixed noise
$\sigma = 25$
$p = 15,30,45$

Image	($\sigma = 25$) p	Training method		
		Proposed	Without division	Without skip connection
Test images	15%	**29.24**	27.72	28.07
	30%	**28.54**	26.82	27.65
	45%	**27.22**	25.46	26.53
BSDS300	15%	**26.83**	25.84	26.37
	30%	**25.95**	24.93	25.62
	45%	**24.8**	23.74	24.53

Conclusion

・We propose a new method for removing mixed noise based on CNN.

→ Blind denoising is achieved by training with various noise levels

→ Robustness against the noise is obtained by not using impulse noise removal method as preprocessing.

Thanks!

Source code is available at:
http://tkhm.elec.keio.ac.jp/achievement