Noise evaluation and reduction

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Introduction

- Problem
- Solution
- Evaluation
- Results and Discussion
- Conclusion

Problem

- Noise:
  Noise is an unwanted component of the image which can be additive or multiplicative.

- Denoise:
  Denoise is popular solution for photography or remove noise in images processing.

Type of noise

- Salt and Pepper Noise
- Gaussian Noise
- Quantization Noise
- Speckle Noise

Salt and Pepper Noise(Impulse Noise)

Original image (left column) and salt and pepper noise (right column).

Gaussian Noise(Amplifier Noise)

Original image (left column) and gaussian noise (right column).

Quantization Noise(Uniform Noise)

Original image (left column) and quantized image to 6 bits (right column).

Speckle Noise(Multiplicative Noise)

Original image (left column) and image corrupted with speckle noise (right column).

Solution

- Spatial Filtering
- Frequency domain filtering

Type Of Filtering

- Median Filter
- Average Filter
- Gaussian Filter
- Wiener Filter

Median Filter

The median filter is a nonlinear digital filtering technique, often used to remove noise from an image or signal (speckle noise & salt-pepper noise)

234	147	225	214	134
231	123	121	223	189
124	223	156	178	196
219	125	211	178	124
210	185	221	189	134

		178		

Example of median computation

Average Filter

The idea of average filtering is simply to replace each pixel value in an image with the average value of its neighbors, including itself.

$$k(u, v) = \frac{1}{M} \sum_{(p,q) \in N} i(p, q)$$

Filter 3×3

$$\frac{1}{9}\begin{array}{|c|c|c|}\hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline\end{array}$$

Average Filter(1)

Filter 5×5

$$\frac{1}{25}\begin{array}{|c|c|c|c|c|}\hline 1&1&1&1&1\\\hline 1&1&1&1&1\\\hline 1&1&1&1&1\\\hline 1&1&1&1&1\\\hline 1&1&1&1&1\\\hline\end{array}$$

Filter 7×7

$$\frac{1}{49}\begin{array}{|c|c|c|c|c|c|c|}\hline 1&1&1&1&1&1&1\\\hline 1&1&1&1&1&1&1\\\hline 1&1&1&1&1&1&1\\\hline 1&1&1&1&1&1&1\\\hline 1&1&1&1&1&1&1\\\hline 1&1&1&1&1&1&1\\\hline 1&1&1&1&1&1&1\\\hline\end{array}$$

Example of Average Filter

Gaussian Filter

The Gaussian smoothing operator is a 2-D convolution operator that is used to 'blur' images and remove detail and noise.

The Gaussian kernel in dimension 2:

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2 + y^2}{2\sigma^2}}$$

Where σ is the standard deviation of the distribution.

Define the Gaussian mask(σ=2):

Filter 3×3

$$\frac{1}{16}\begin{array}{|c|c|c|}\hline 1 & 2 & 1 \\ \hline 2 & 4 & 2 \\ \hline 1 & 2 & 1 \\ \hline \end{array}$$

Gaussian Filter(1)

Filter 5×5

$$\frac{1}{273}\begin{array}{|c|c|c|c|c|}\hline 1 & 4 & 7 & 4 & 1 \\ \hline 4 & 16 & 26 & 16 & 4 \\ \hline 7 & 26 & 41 & 26 & 7 \\ \hline 4 & 16 & 26 & 16 & 4 \\ \hline 1 & 4 & 7 & 4 & 1 \\ \hline \end{array}$$

Filter 7×7

$$\frac{1}{1003}\begin{array}{|c|c|c|c|c|c|c|}\hline 0 & 0 & 1 & 2 & 1 & 0 & 0 \\ \hline 0 & 3 & 13 & 22 & 13 & 3 & 0 \\ \hline 1 & 13 & 59 & 97 & 59 & 13 & 1 \\ \hline 2 & 22 & 97 & 159 & 97 & 22 & 2 \\ \hline 1 & 13 & 59 & 97 & 59 & 13 & 1 \\ \hline 0 & 3 & 13 & 22 & 13 & 3 & 0 \\ \hline 0 & 0 & 1 & 2 & 1 & 0 & 0 \\ \hline \end{array}$$

Wiener Filter

Weiner filter is a frequency-domain method for image denosing.

- Assumption
- Requirement
- Performance criterion

Evaluation

The MSE is a measure of the quality of an estimator—it is always non-negative, and values closer to zero are better.

$$\mathrm{MSE} = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}(f'_{ij} - f_{ij})^2$$

Evaluation(1)

Peak signal-to-noise ratio(PSNR) is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation.

$$PSNR = 10 \log_{10} \frac{R^2}{MSE}$$

Results and Discussion

SWARMS project dataset

Construction Sites

Figure 1: Evaluated construction site photos. From left to right: construction1, construction2, construction3, construction4, construction5

Evaluated metrics for construction site photos

Photo	Type	Metric	Median	Average	Gaussian	Wiener
construction1	Noise	MSE	0.0125	0.0251	0.012	0.0084
		PSNR	67.1535	64.1264	67.3409	68.8738
	Denoise	MSE	0.0097	0.022	0.0095	**0.007**
		PSNR	68.269	64.7115	68.3762	**69.6511**
construction2	Noise	MSE	0.0096	0.0219	0.0096	0.0075
		PSNR	68.298	64.7271	68.2967	69.3898
	Denoise	MSE	0.0055	0.0166	0.0056	**0.0044**
		PSNR	70.7071	65.9348	70.6237	**71.654**
construction3	Noise	MSE	0.0078	0.0178	0.0077	0.0061
		PSNR	69.2093	65.638	69.2572	70.2559
	Denoise	MSE	0.0034	0.0122	0.0035	**0.0028**
		PSNR	72.761	67.2713	72.6781	**73.6324**
construction4	Noise	MSE	0.0065	0.0183	0.0067	0.0054
		PSNR	69.9904	65.5003	69.8929	70.8107
	Denoise	MSE	0.0026	0.0144	0.0031	**0.0022**
		PSNR	73.9221	66.5571	73.1714	**74.65**
construction5	Noise	MSE	0.0125	0.0351	0.0131	0.0098
		PSNR	67.1789	62.6729	66.9615	68.2047
	Denoise	MSE	0.0048	0.0243	0.0056	**0.0046**
		PSNR	71.3083	64.2764	70.6356	**71.5275**

Rubbish

Figure 2: Evaluated rubbish photos. From left to right: rubbish1, rubbish2, rubbish3, rubbish4, rubbish5

Evaluated metrics for rubbish photos

Photo	Type	Metric	Median	Average	Gaussian	Wiener
rubbish1	Noise	MSE	0.007	0.0198	0.007	0.0053
		PSNR	69.6741	65.1589	69.6536	70.8804
	Denoise	MSE	0.0032	0.0156	0.0036	**0.0025**
		PSNR	73.1106	66.1969	72.5825	**74.1694**
rubbish2	Noise	MSE	0.0078	0.0173	0.0076	0.0061
		PSNR	69.2119	65.7582	69.3064	70.2561
	Denoise	MSE	0.0036	**0.00126**	0.0038	0.0029
		PSNR	72.5146	67.1263	72.3851	**73.4524**
rubbish3	Noise	MSE	0.0158	0.0336	0.015	0.0115
		PSNR	66.1394	62.8625	66.3823	67.5195
	Denoise	MSE	0.0083	0.0246	0.0081	**0.0063**
		PSNR	68.9656	64.2139	69.0718	**70.1636**
rubbish4	Noise	MSE	0.0313	0.0567	0.0287	0.0235
		PSNR	63.1696	60.5959	63.5549	64.4181
	Denoise	MSE	0.0207	0.0424	0.0185	**0.0161**
		PSNR	64.9661	61.8601	65.4527	**66.0756**
rubbish5	Noise	MSE	0.0096	0.0176	0.0092	0.007
		PSNR	68.3119	65.677	68.4872	69.698
	Denoise	MSE	0.0055	0.0123	0.0053	**0.004**
		PSNR	70.7050	67.2474	70.9133	**72.0813**

Pagoda

Figure 3: Evaluated pagoda photos. From left to right: pagoda1, pagoda2, pagoda3, pagoda4, pagoda5

Evaluated metrics for pagoda photos

Photo	Type	Metric	Median	Average	Gaussian	Wiener
pagoda1	Noise	MSE	0.013	0.0168	0.0115	0.0068
		PSNR	66.9999	65.8739	67.5091	69.7993
	Denoise	MSE	0.0098	0.0141	0.0093	**0.0055**
		PSNR	68.2117	66.6490	68.4598	**70.7544**
pagoda2	Noise	MSE	0.0138	0.0189	0.0122	0.0076
		PSNR	66.7404	65.3739	67.2818	69.3011
	Denoise	MSE	0.0098	0.0145	0.0088	**0.0053**
		PSNR	68.2338	66.5220	68.6970	**70.9009**
pagoda3	Noise	MSE	0.0150	0.0215	0.0131	0.0081
		PSNR	66.3743	64.8131	66.9631	69.0515
	Denoise	MSE	0.0114	0.0177	0.0102	**0.0065**
		PSNR	67.5543	65.6549	68.0291	**70.0034**
pagoda4	Noise	MSE	0.0116	0.0229	0.0106	0.0069
		PSNR	67.4972	64.5418	67.8751	69.7300
	Denoise	MSE	0.0080	0.0188	0.0072	**0.0047**
		PSNR	69.1060	65.3952	69.5399	**71.4029**
pagoda5	Noise	MSE	0.0141	0.0230	0.0125	0.0086
		PSNR	66.6335	64.5060	67.1643	68.8033
	Denoise	MSE	0.0104	0.0179	0.0087	**0.0062**
		PSNR	67.9741	65.6092	68.7310	**70.2064**

Pond

Figure 4: Evaluated pond photos. From left to right: pond1, pond2, pond3, pond4, pond5

Evaluated metrics for pond photos

Photo	Type	Metric	Median	Average	Gaussian	Wiener
pond1	Noise	MSE	0.0151	0.0374	0.0148	0.0116
		PSNR	66.3488	62.4067	66.4381	69.5
	Denoise	MSE	0.0071	0.0267	0.0071	**0.0057**
		PSNR	69.6156	63.8625	69.6193	**70.5647**
pond2	Noise	MSE	0.009	0.0161	0.087	0.0066
		PSNR	68.5651	66.0539	68.7473	69.9595
	Denoise	MSE	0.0049	0.0118	0.0049	**0.0037**
		PSNR	71.1950	67.4075	71.1985	**72.4594**
pond3	Noise	MSE	0.0103	0.0181	0.0095	0.0071
		PSNR	68.0057	65.5457	68.3309	69.5910
	Denoise	MSE	0.0063	0.0136	0.0059	**0.0045**
		PSNR	70.1294	66.7905	70.4278	**71.5971**
pond4	Noise	MSE	0.0085	0.0148	0.0082	0.0062
		PSNR	68.8176	66.4207	68.9979	70.1919
	Denoise	MSE	0.0044	0.0103	0.0045	**0.0034**
		PSNR	71.7345	67.9993	71.5601	**72.7996**
pond5	Noise	MSE	0.0111	0.0191	0.0098	0.0068
		PSNR	67.6856	65.3228	68.2256	69.7923
	Denoise	MSE	0.0076	0.0149	0.0065	**0.0044**
		PSNR	69.3244	66.4011	70.0243	**71.7026**

Discussion

Photo	Median	Average	Gaussian	Weiner
construction1	9.762	3.038	2.161	15.524
rubbish1	9.145	3.187	2.158	11.795
pagoda1	8.909	2.998	2.170	12.372
pond1	7.543	2.68	1.826	7.329

Method runtimes (in milliseconds)

Conclusion

- The best of results
  Wiener filter with MSE is minimum mean square error and it is maximum PSNR.
- Disadvantage
  At all method, this method has runtimes which is the longest .
- Future development
  Improvement of the proposed method over the existing approaches in terms of visual quality.

THANK YOU !!!