International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 2 (2018) pp. 840-848

Architecture for Automatic Detection of Noise and Adaptive Approach for Noise Removal on Road Images

Suwarna Gothane
Associate Professor, Computer Science and Engineering Department, CMR Technical Campus, Hyderabad, India,
Research Scholar, Department of Computer Science and Engineering, Sant Gadge Baba Amravati University, Amravati, Maharashtra, India.
Orcid: 0000-0003-0453-1717

Dr M V Sarode
Head of Computer Engineering, Government Polytechnic Yavatmal, Yavatmal Maharashtra, India.
Orcid-:0000-0002-2235-2053

Dr. V. M. Thakre
Professor, Department of Computer Science, Sant Gadge Baba Amravati University, Amravati, Maharashtra, India.

Abstract

With the fastest growing road transport mode in India and worldwide, now this is the demand from the present research movements to provide enhanced measures for road safety, maintenance and traffic control. The safety and traffic situations are depended partly on the road conditions, especially in Indian scenarios. Hence, the preventive measures for the road conditions significant factor to consider for road authorities. Various research attempts are been implements and studies in order to establish a process to automate the maintenance cycle of the roads. Nevertheless, the complete cost propositions of those models are not completely justified. Moreover, the trade-off between the accuracy observational time complexity is always the bottleneck for higher performance improvements. Also, various studies have also demonstrated that, a significant amount of accuracy will depend on the quality of the input images. The quality of the images can easily be improved by using various high definition capture devices. This proposition certainly will lead towards higher cost factor and low value propositions. Thus, improving the image quality is the basic need to improve the accuracy for detecting the road conditions. Also, adding to this complexity challenge, road conditions are captured in various lighting conditions and using variety of capture devices, disjointed by quality and method of capturing. This augments the presence of noise in the input images to a greater extend, thus influencing the results in negative directions. Henceforth, the first and foremost challenge of this direction of the research is to formulate a method or framework to identify and reduce various types of noises and adaptively remove the images. This work demonstrates a novel approach to detect and restore noisy images using enhanced finite normal density mixture method. The final outcome of this work is the novel framework with incremental order of improvements in noise removal from 10% to 80% based on the nature of the noise in the image.

Keywords: Legendre Moments, Salt & Pepper Noise Removal, Gaussian Noise Removal, Poisson Noise Removal, Speckle Noise Removal, Image Reconstruction

INTRODUCTION

The digital images are the most common format for visual data representation in all the popular fields of study. The resent research outcomes on image representation for road and safety influence the research and further to improve the image pre-processing phases. The images are captured using various devices and under various conditions, thus tend to comply noisy images. The noise present in the images disrupts the processing in improving the analysis for road condition determinations. Thus, the demand from the modern research is to improve the pre-processing under the image accumulation phase.

Consideration of the road image for determining the road conditions or the traffic analysis or for the automation of the maintenance tasks is high. A number of research attempts are made for better and improved image capturing process, image storage, image retrieval and further image mapping or matching process. Nevertheless, these process results are solely depended on the quality of the images. The quality of the images further depends on the capturing devices and capturing techniques. Henceforth, the improvements of the image capturing devices were also been under focus for a long work. Nonetheless, improvements for the hardware capture devices are subjected to enhanced cost. Thus, the research attempts made are more likely towards software capture agents. The popular research outcomes have recommended use of estimation techniques such As moments algorithms. The notable work by B. Chen at al. [1] clearly demonstrates the scope for improvement in image restoration and enhancements. Thus this work demonstrates the use of modified moments algorithms as image enhancer under the pre-processing phase for further improvements on the road condition processing.

The rest of the work is furnished such as in the section – II the outcomes from the parallel researches are discussed with the standard moments frameworks. In the section – III, based on the types and natures of the capture devices, the noises are classified. Later this information is considered as predictive removal of the noises from the captured images. In the next section, Section – IV, the focus of this work is discussed as the novel algorithm is proposed. Further to make the proposed algorithm stable for comparison and implementation, the mathematical model is explained in Section – V and Section – VI. Followed by the results are furnished and explained in the Section – VII and the work presents the final conclusion in the Section – VIII.

REVIEW OF THE PARALLEL RESEARCH OUTCOMES

In this section of the work, the outcomes from the recent researches are been analysed. The image correction method using moment algorithms is fairly modern and there are significantly limited number of proposal and results available to understand for comparison. Nevertheless, this also contributes towards the motivation to enhance moment algorithms for image restorations

The moment algorithms as a technique used to calculate the weighted average for the designated properties of the images. The considerable outcome from H. Zhang et al. [2] for image recognition for the blurred images using Legendre moment demonstrates a significant motivation for further researches. The captured images from various devices due to human errors and environment conditions are bound to have the rotational effects. The work by H. Zhu et al. [3] demonstrate the use of Zernike moment descriptor to nullify the effects and present further processing benefits. The moment algorithms are separated by nature for various purposes and the capture images tend to include various noisy and blurry effects. Thus a number of research attempts are made to include benefits from various moment algorithms to resolve pre-processing issues. The work demonstrated by X. Dai et al. [4] is one of the attempts to influence the thoughts in this direction. The pre-processing is a time complex event and cannot be ignored. Thus mapping a pattern to predict the blurriness in the images helps the predictive analysis to be applied and can significantly reduce the time complexity. The work by J. Flusser et al.[5] considers this phenomenon and demonstrates significant improvements in the results.

Another bottleneck for image improvements for road images is separation of the target areas from the backgrounds. The target areas and the backgrounds defers barely on the pixel density. As demonstrated by G. S. Xu et al. [6], the moment algorithms also can be deployed to resolve this issues. The techniques proposed by Xu et al. are further enhanced by Y. Yao et al. [7] and R. Breder et al. [8].

Yet another very distinguished technique used by S. W. Jung et al. [9] demonstrates the use of fuzzy projection for image de-blurring. Nevertheless, this work considers nontrivial solutions towards this problem and focuses on moment algorithms.

Further, in this section, the generic moment approaches are been considered and explained:

A. Raw Moment

For a simple two-dimensional function, denoted by $f(a, b)$, the raw moment of order (x, y) can be defined as

$$M_{xy} = \int_{-\alpha}^{+\alpha}\int_{-\alpha}^{+\alpha} a^x.b^y.f(a,b).da.dy \tag{1}$$

For all positive integers of x and y

The function $f(a,b)$ denoting any greyscale image with pixel intensity of I(a, b) will be denoting the moment as

$$M_{xy} = \sum_a \sum_b a^x.b^y.I(a,b) \tag{2}$$

In order to simply the calculations by considering the probabilistic measure for image analysis, the Eq. 2 needs to be normalized by the $\sum_a \sum_b I(a,b)$

B. Central Moment

For a simple two-dimensional function, denoted by $f(a,b)$, the central moment of order (x, y) can be defined as

$$\mu_{xy} = \int_{-\alpha}^{+\alpha}\int_{-\alpha}^{+\alpha} (a-\bar{a})^x.(b-\bar{b})^y.f(a,b).da.dy \tag{3}$$

Where the $\overline{a}$ and $\overline{b}$ are the generic components of the centroid of the image and can be defined as

$$\overline{a} = \frac{M_{10}}{M_{00}} \text{ and } \overline{b} = \frac{M_{01}}{M_{00}} \quad (4)$$

In case of a digital image, the Eq. 4 can be represented as the following:

$$\mu_{xy} = \sum_a \sum_b (a-\overline{a})^x.(b-\overline{b})^y.f(a,b) \quad (5)$$

The central moments for order k can be represented as

$$\mu_{xy} = \sum_{k_1}^{x} \sum_{k_2}^{y} \binom{x}{k_1}.\binom{y}{k_2}.(-\overline{x})^{(x-k_1)}.(-\overline{y})^{(y-k_2)}.M_{k_1 k_2} \quad (6)$$

The central moments are considered as translation invariant.

C. Scale Invariant Moment

The moment of order (x + y) where x + y ≥ 2 can be obtained by dividing the central moment with 0th moment as following:

$$M_{xy} = \frac{\mu_{xy}}{\mu_0^{(1+\frac{x+y}{2})}} \quad (7)$$

The scale invariant is neutral for scale change.

CLASSIFICATION OF NOISES & BLURRINESS

The reduced visibility images causes less detailed information in the images. This factor is proven by various researchers and the most notable work by L. Li et al.[10] and V. Ojansivu et al. [11].

The objects in the images are generally differentiated by the pixel difference between the object and the background at the object edges. The blurriness of the image actually reduces the pixel difference at the object edges as suggested by B. Mahdian et al.[12] in the year of 2007.

The blurriness of the image can be measured in terms of units of lengths. The length of the images denotes the blurriness of the image [Table – 1].

Table I: Blur Value Range [13]

Capture Agent Type	**Range of Blur Value (In MM)**
Gamma Radiation Based Capture Devices	10 to 2
Ultrasonic Capture Devices	5 to 2.1
MR Imaging Devices	3.4 to 1
Thermal Capture Agents	2 to 1.3
Motion Sensor Capture Devices	2.8 to 0.3
Radio Active Camera	0.5 to 0.1

PROPOSED NOVEL ALGORITHM

In this section, this work defines the proposed novel algorithm:

Step -1. Accept the image from the capture devices

Step -2. Calculate the schema for the image and store the image with pixel value

Step -3. Analyse accepted image for two phases
- a. Start the Restoration Phase
- b. Calculate the image properties as:
  - i. Calculate the pixel density
  - ii. Calculate the pixel distortion
  - iii. Calculate the pixel displacement average
- c. Start the Noise Removal Phase
  - i. Calculate the pixel average distortion
  - ii. Identify the noise type
  - iii. Calculate the signal-to-noise ratio

Step -4. Restore the image and remove the noise using multiple iterative moment
- a. Compare the signal-to-noise ratio
- b. If the ratio is minimum, then terminate the process
- c. Else, repeat Step – 3.

The graphical representation of the algorithm is furnished here [Figure – 1].

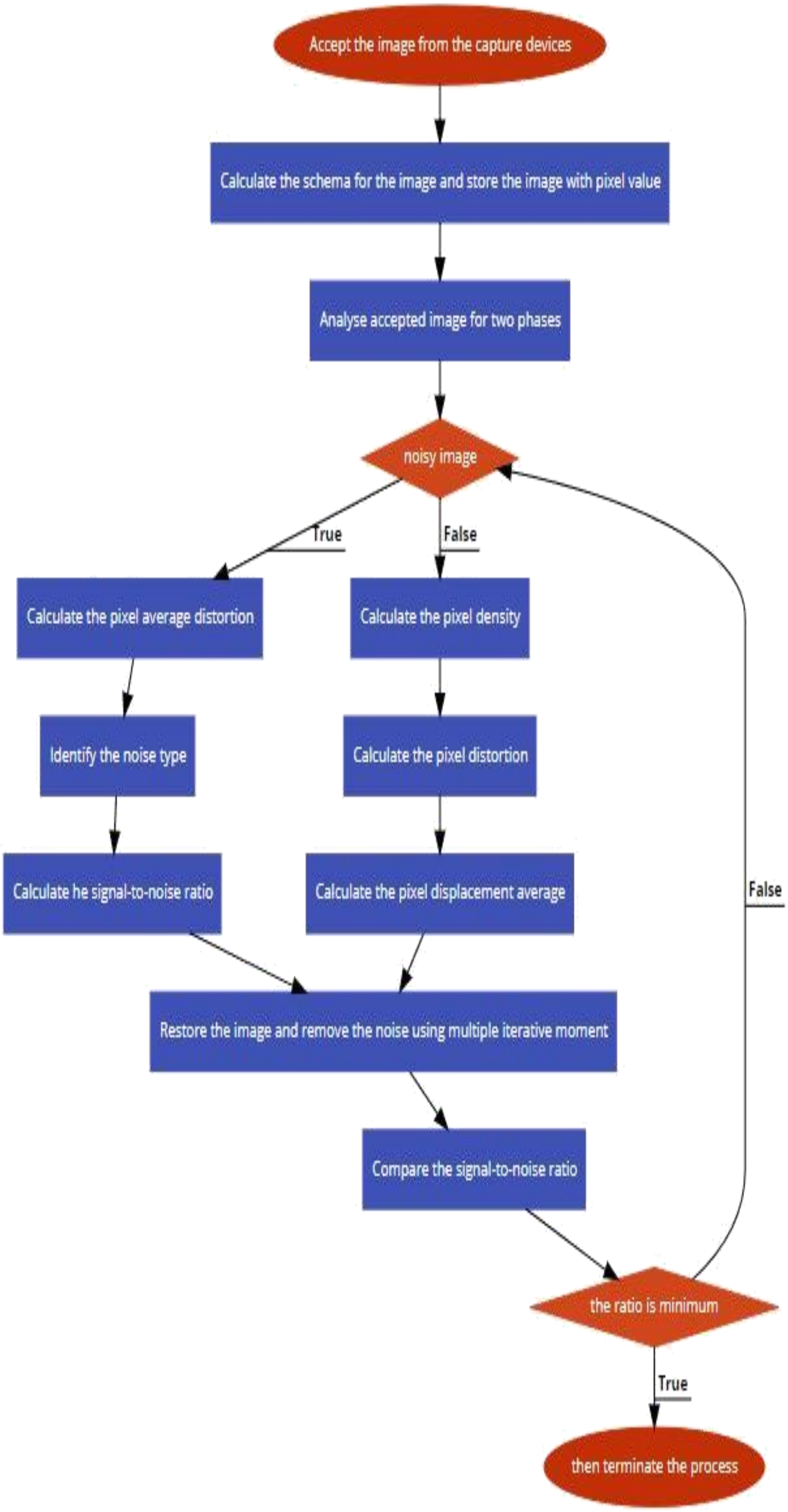

Figure 1. Control Flow of the Proposed Algorithm

MATHEMATICAL MODEL FOR THE AUTOMATIC IDENTIFICATION OF BLUR AND NOISE IMAGES

In this section of the work the novel proposed algorithm is elaborated using the mathematical modelling technique:

Legendre Moment for of order (a + b) is defined as

$$\lambda_{ab} = \frac{(2a+1)(2b+1)}{4}\int_{-1}^{+1}\int_{-1}^{+1} P_a(i).P_b(i,j).didj \tag{8}$$

Where a, b is ranging from 1 to ∞.

Hence the kth order Legendre polynomial is written as:

$$P_k(i) = \frac{(2k)!}{2^k (k!)^2} i^k - \frac{(2k-k)!}{2^k !(k-1)!(k-2)!} i^{k-2} + ... \quad \text{Kth Term (9)}$$

Where, D(k) = k/2 or (k-1)/2, is an positive integer.

The recurrence relation for calculating the Legendre polynomial is as following:

$$(k+1)P_{k+1}(i) - (2k+1)iP_k(i) + kP_{k-1}(i) = 0 \tag{10}$$

As discussed in the previous section of this work, any image function f (a, b) using Legendre polynomial can be defined as following:

$$f(i,j) = \sum_{a=0}^{\infty}\sum_{b=0}^{\infty} \lambda_{ab} P_a(i).P_b(j) \tag{11}$$

Where, λ_{ab} can be calculated on the closed boundary of the same image.

$$f(i,j,L) = \sum_{a=0}^{\infty}\sum_{b=0}^{\infty} \lambda_{a-b,b} P_{a-b}(i).P_b(j) \tag{12}$$

When the Legendre moment of order (a + b) is less than or equal to L, the image descriptor, then the image function can be represented as following:

$$f(i,j,a_{\max},b_{\max}) = \sum_{a=0}^{a_{\max}}\sum_{b=0}^{b_{\max}} \lambda_{a,b} P_a(i).P_b(j) \tag{13}$$

MATHEMATICAL MODEL FOR THE PROPOSED ADAPTIVE METHOD

The two dimensional Legendre Moment for the blurred image of g (a, b) can be defined as:

$$L_{x,y}(g) = \int_{-1}^{+1}\int_{-1}^{+1} P_x(a).P_y(b).g(a,b).dadb \tag{14}$$

With the understanding of blurriness effect on the image, the image pixel will be multiplied by random value generated by the noise function

$$L_{x,y}(g) = \int_{-1}^{+1}\int_{-1}^{+1} P_x(a).P_y(b).(f*h).dadb \tag{15}$$

The shift of the pixel values are being calculated in order to find the moment value

$$L_{x,y}(g) = \int_{-1}^{+1}\int_{-1}^{+1} P_x(a).P_y(b).(\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} h(i,j)f(a-i,b-j)didj).dadb \tag{16}$$

Hence the proposed Legendre moment of the blurred image can be represented as

$$L_{x,y}(g) = \int_{-1}^{+1}\int_{-1}^{+1} h(i,j).(\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} P_x(a+i).P_y(b+j)f(a,b)dadb).didj \tag{17}$$

Hence equation 17 defines the calculation of proposed Legendre Moment for blurred image.

Thus the proposed novel framework for restoring the blurred image using Legendre Moment is presented in this work [Figure – 2].

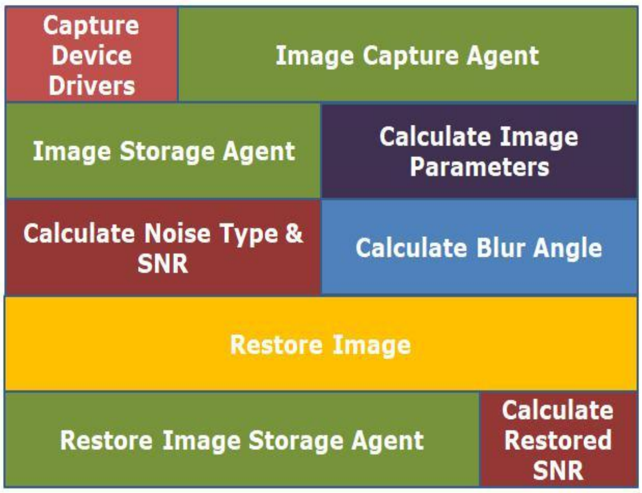

Figure 2. Proposed Framework for the Image Restoration Process

RESULTS AND DISCUSSIONS

Henceforth, based on the proposed framework and algorithms this work analyses the obtained results on various factors

Adaptive Process for Noise Type Identification Results

The first outcome of this work is to identify the type of the noise in the captured images. The identification of the noise type will decide the number of iterations and noise removal technique. The obtained results are furnished here [Table – 2]

Table II: Noise Type Identification

Sample Image Data	Actual Noise Type	Identified Noise Type	Success Analysis
Image – 1	Salt & Pepper	Salt & Pepper	Match
Image – 2	Gaussian	Gaussian	Match
Image – 3	Poisson	Poisson	Match
Image – 4	Speckle	Speckle	Match
Image – 6	Gaussian	Gaussian	Match
Image – 7	Poisson	Poisson	Match
Image – 8	Speckle	Speckle	Match
Image – 9	Salt & Pepper	Salt & Pepper	Match
Image – 10	Gaussian	Gaussian	Match
Image – 11	Poisson	Poisson	Match
Image – 12	Speckle	Speckle	Match
Image – 13	Salt & Pepper	Salt & Pepper	Match
Image – 14	Gaussian	Gaussian	Match
Image – 15	Poisson	Poisson	Match
Image – 16	Speckle	Speckle	Match
Image – 17	Gaussian	Gaussian	Match
Image – 18	Poisson	Poisson	Match
Image – 19	Speckle	Speckle	Match
Image – 20	Gaussian	Gaussian	Match

Hence, this is natural to understand that the proposed novel adaptive identification method generates the correct identification of the noise type for all the sample test images, thus resulting into 100% success rate

The success rate is visualized in the graphical format as well [Figure – 3].

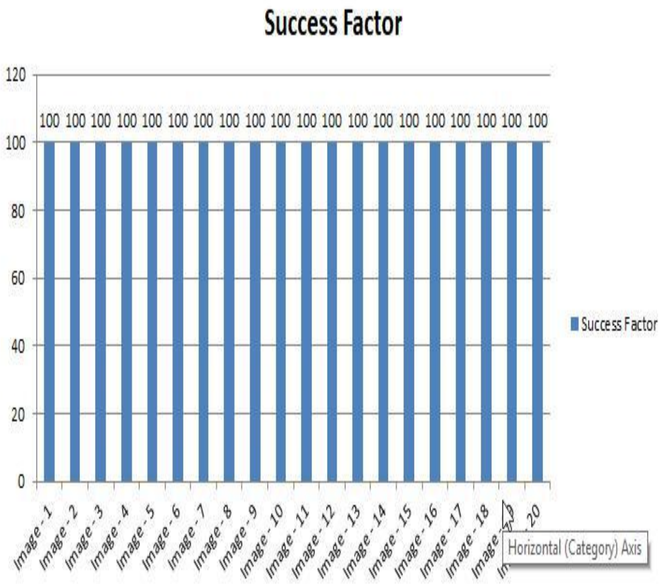

Figure 3. Adaptive Noise Identification Success Rate

A. *Proposed Adaptive Blurred Angle Estimation Results*

The second outcome of this proposed framework is to identify the angle of the images causing the blur in the captured images. This result will help in deciding the restoration angle factor during restoration process. The results are furnished here [Table – 3]

Hence, from the results it is natural to realize that, the difference between the actual angle of the image and the estimated angle of the image is expected to be zero. In case the difference is positive, then the estimated angle is lower than the actual distortion angle and if the difference is negative, then the estimated angle is higher than the actual distortion angle

Table III: Angle Estimation

Sample Image Data	Actual Blurred Angle	Estimated Blurred Angle	Difference (Numeric) = Actual – Estimated
Image – 1	190	192	-2
Image – 2	160	160	0
Image – 3	195	196	-1
Image – 4	164	164	0
Image – 5	187	186	1
Image – 6	166	166	0
Image – 7	150	150	0
Image – 8	201	200	1
Image – 9	159	159	0
Image – 10	176	176	0
Image – 11	196	195	1
Image – 12	153	152	1
Image – 13	155	155	0
Image – 14	155	154	1
Image – 15	170	170	0
Image – 16	167	167	0
Image – 17	166	166	0
Image – 18	153	152	1
Image – 19	190	192	-2
Image – 20	155	154	1

Nevertheless, the equal or close to equal estimation demonstrates the better result as obtained in this work. The comparison is realised in graphical format [Figure – 4].

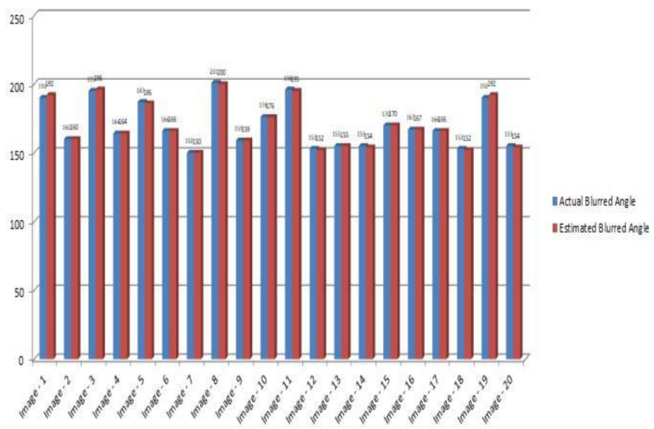

Figure 4. Adaptive Angle Identification comparison – Actual Vs Obtained

B. Proposed Adaptive Image Length Restoration Results

The third outcome of this work is to restore the image length after partial restoration process for improvement of the resolution. The length denotes the resolution of the image irrespective of the pixel density and depends on the representation mechanism used to calculate the spatial resolution of the image. The obtained results are furnished here [Table – 4]

Table IV: Image length estimation

Sample Image Data	Original Length	Restored Length	Success Analysis
Image – 1	9	9	Match
Image – 2	4	4	Match
Image – 3	6	6	Match
Image – 4	4	4	Match
Image – 5	3	3	Match
Image – 6	8	8	Match
Image – 7	8	8	Match
Image – 8	5	5	Match
Image – 9	7	7	Match
Image – 10	6	6	Match
Image – 11	9	9	Match
Image – 12	3	3	Match
Image – 13	5	5	Match
Image – 14	7	7	Match
Image – 15	8	8	Match
Image – 16	9	9	Match
Image – 17	4	4	Match
Image – 18	6	6	Match
Image – 19	3	3	Match
Image – 20	10	10	Match

Thus, it is natural to recognize that the proposed adaptive image length restoration process is generating 100% accurate results [Figure – 5].

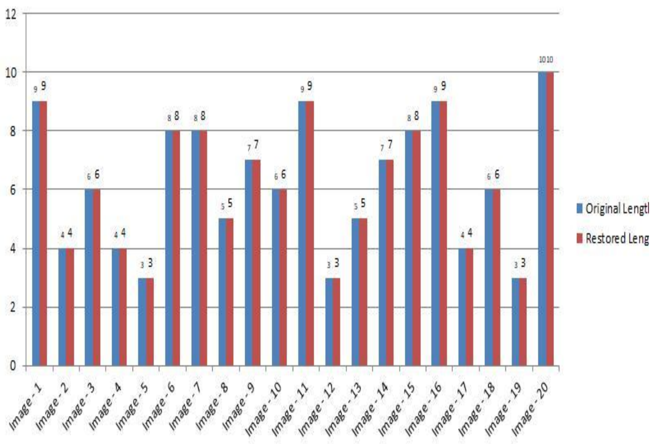

Figure 5. Adaptive Length Identification comparison – Actual Vs Obtained

C. Signal to Noise Ratio Analysis

After the restoration process, it is significant measure to calculate the sensitivity of the image. In the signal to noise ratio have increased, then it is to be identified as ineffective restoration process. Hence, the signal to noise ratio must reduce after the restoration process. The obtained results are been furnished here [Table – 5].

Table V. SNR Analysis

Sample Image Data	SNR for Noisy Image	SNR for Restored Image
Image – 1	0.002	0.0013
Image – 2	0.0029	0.0014
Image – 3	0.002	0.0014
Image – 4	0.0023	0.0013
Image – 5	0.0024	0.001
Image – 6	0.0028	0.0013
Image – 7	0.0028	0.0013
Image – 8	0.002	0.0011
Image – 9	0.0021	0.0011
Image – 10	0.0029	0.0014
Image – 11	0.0026	0.0014
Image – 12	0.0024	0.001
Image – 13	0.003	0.0014
Image – 14	0.0024	0.0015
Image – 15	0.0024	0.0013
Image – 16	0.002	0.0012
Image – 17	0.0021	0.0015
Image – 18	0.0025	0.0014
Image – 19	0.0022	0.0011
Image – 20	0.0023	0.0011

Identifying from the results, this is generic to identity that the testing images are similarly noise affected and thus the steady restoration process demonstrates the constant improvements. The results are been visualised graphically to realise the amount of improvements [Figure –6].

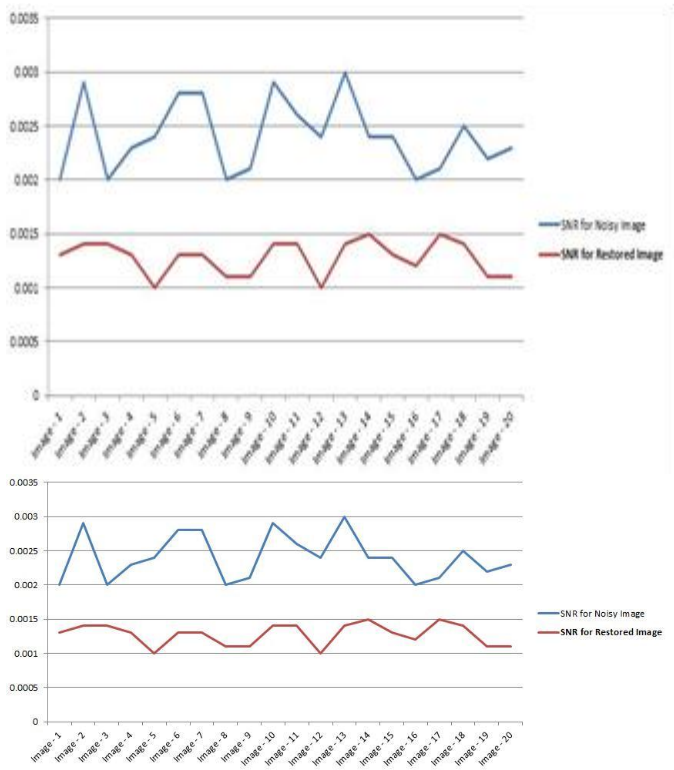

Figure 6. Signal to Noise Ratio Analysis – Actual Vs Obtained

Hence, with the complete analysis of the results, the claims made by this work are justified and proposed improved are satisfied.

This work considers a variety of road images captured from Indian road network for analysis [Figure – 7]

Figure 7. Sample Input Set

CONCLUSION

In the course of enhancements of road transportation systems, identification of the road condition for making the road the most preferred way to choose for various purposes have become the significant demand for the research. The maintenance of the roads is manual and needs to be enhanced in order to save the time. Thus, automatic detection of the road conditions is the vital demand for the safety and maintenance organizations. During the study this work demonstrates that the improvement on automatic detection of the road condition also depends on the image quality captured. Thus making the input image noise and blur free for further analysis is the primary requirement. The noises in the captured images are strongly influenced by the type of the capture device and impose variety of noise type and blur factors. Hence, this work demonstrates a novel adaptive approach to detect and restore noise and blur images. The result obtained from this work is significant and ensures improvements in the analysis of road conditions, thus ensuring better roads for the world.

REFERENCES

[1] B. Chen, H. Shu, H. Zhang, G. Coatrieux, L. Luo, J. L.Coatrieux, "Combined invariants to similarity transformation and to blur using orthogonal Zernike moments", IEEE Trans. Image Process., vol. 20, no. 2, pp.345-360, 2011.

[2] H. Zhang , H. Shu , G.-N. Han , G. Coatrieux , L. Luo and J. L. Coatrieux,"Blurred image recognition by Legendre moment invariants", IEEE Trans. Image Process., vol. 19, no. 3, pp.596 - 611, 2010.

[3] H. Zhu , M. Liu , H. Ji and Y. Li "Combined invariants to blur and rotation using Zernike moment descriptors", Pattern Anal. Appl., vol. 3, no. 13, pp.309 -319, 2010.

[4] X. Dai, H. Zhang , H. Shu and L. Luo, "Image recognition by combined invariants of Legendre moment", Proc. IEEE ICIA, pp.1793-1798, 2010.

[5] J. Flusser , T. Suk , B. Zitová, "Moments and Moment Invariants in Pattern Recognition", Wiley,2009.

[6] Xu, G. S, "Sub-pixel edge detection based on curve fitting", Proc. 2nd Int. Conf. Information and Computing Science, Manchester, UK, pp. 373-375,May 2009.

[7] Yao, Y., Ju, H., "A sub-pixel edge detection method based on Canny operator", Proc. 6th Int. Conf. Fuzzy Systems and Knowledge Discovery, Tianjin, China, pp. 97-100,August 2009.

[8] Breder, R., Estrela, V., V.,de Assis, J. T, "Sub-pixel accuracy edge fitting by means of B-spline", Proc. IEEE Int. Workshop Multimedia Signal Processing, Rio de Janeiro, Brazil, pp.1-5,October 2009.

[9] S. W. Jung, T. H. Kim and S. J. Ko "A novel multiple image deblurring technique using fuzzy projection onto convex sets", IEEE Signal Process. Lett., vol. 16, no. 3, pp.192 -195, 2009.

[10] L. Li and G. Ma, "Recognition of degraded traffic sign symbols using PNN and combined blur and affine invariants", Proc. 4th ICNC, vol. 3, pp.515 - 520, 2008.

[11] V. Ojansivu and J. Heikkilä "Image registration using blur-invariant phase correlation", IEEE Signal Process. Lett., vol.14, no. 7, pp.449 -452,2007

[12] B. Mahdian and S. Saic, "Detection of copy-move forgery using a method based on blur moment invariants", Forensic Sci. Int., vol. 171, no. 2/3, pp.180-189,2007.