Effect of Diurnal Changes on the Quality of Digital Images

Priti Rajput [1], Santoresh Kumari [2], Sandeep Arya [3], Parveen Lehana [3,*]

[1]*Directorate of Economics & Statistics, J & K, India*
[2]*Department of Computer Science, MIET Jammu, J & K, India*
[3]*Department of Physics & Electronics, University of Jammu, Jammu, J & K, India*

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ABSTRACT

Prospective outdoor imaging depends on diurnal changes through the day and it needs an understanding of light and its effects on quality of the images. In this paper, investigations have been carried out to study the effect of diurnal changes on the quality of the images taken at regular intervals of one hour from sunrise to sunset in a sunny day. For investigating the effect of sun orientation, the images were also taken in four different directions i.e. East, West, North, and South. The analysis of the results showed that the picture quality varies with respect to time and the orientation.

1. INTRODUCTION

Digital image processing has several significant applications in the field of weather forecasting, medical resonance imaging, computed tomography, cryptography, and astronomy as well as in other areas of research and technology [1-5]. Generally, image processing is used to extract some valuable features of an image like visualization, image sharpening and restoration, image retrieval, pattern measurements, image recognition, and many more [6-11]. Digital image processing involves a series of complex parameters that help to acquire the better digital image [12]. In image processing, the effect of light relates the "hardness" or "softness" of the image. This effect is perceptible in overcast weather conditions. The sun-drenched light up the whole ambience and creates liveliness in the images. An intense point source may badly affect the images. The change in the direction of light also affects the images.

The exact color of lighting in the images taken can be measured as "color temperature". The units are degree Kelvin [13]. Interestingly, the lower temperature implies warmer color tones (red and yellows) while the higher temperature create cooler colors (blues). Throughout the day, the color temperature of lighting conditions outside changes constantly. It's quite interesting that the color of the lighting conditions changes throughout the day due to position of the sun and the properties of the atmosphere. Air scatters blue light more strongly than the red light. Before sunrise, the sun is stumpy and the illumination floats horizontally across the landscape, thus the illumination comes indirectly from the air that creates a typical blue color [2] [14]. As the sun rises, light penetrates through the thick layers of atmosphere and filters out the blue light, thus giving a warm red color. Similarly, after the sunset, the lighting conditions suddenly become intense blue in shade [2] [13]. Overhead sun at noon produces neutral colours, though it will not produce a good quality

* Tel.: +91 9419200267
E-mail pklehana@gmail.com.

43 image. The colour temperature in shade on a sunny day is extremely high as all of the
44 lighting comes from the blue sky. In afternoon, the colour temperature falls as the sun goes
45 down and the effect become warmer and redder [14]. During cloudy days, the change in
46 colours is much perceptible due to filtering of light in clouds resulting in neutral light
47 throughout the day [14] [15].
48   In this paper, we have investigated the effect of diurnal changes and orientation of
49 the sun on the quality of the open-air natural images. The mathematical formulations of the
50 quality of digital images are presented in the following section. The methodology adopted for
51 the investigations is discussed in Section 3. The results and discussions are presented in
52 Section 4.
53
54 **2. MATHEMATICAL FORMULATION**
55
56 Although visual perception plays a vital role in assessing the quality of a digital image,
57 automatic assessment using objective measures is some time useful for the comparison.
58 One method for this assessment from [16-18] is described here. It uses contrast (σ_n),
59 intensity (μ_n), sharpness (*s*) in normalized form for estimating the quality of the given image
60 [19-22].
61
62 **2.1 Normalized intensity parameter**
63 Let μn be the normalized intensity parameter, then, for grey scale images, normalized
64 intensity parameter can be evaluated as

65 $$\mu_n = \begin{cases} \dfrac{\mu}{255} & \text{for } \mu < 154 \\ 1 - \dfrac{\mu}{255} & \text{otherwise} \end{cases} \qquad (1)$$

66 where μ is the mean contrast of the image. A region is considered to have adequate
67 intensity for 0.4 ≤ μ_n ≤ 0.6 [21] [22].
68
69 **2.2 Normalized contrast parameter**

70 The normalized contrast parameter (σ_n) can be given as

71 $$\sigma_n = \begin{cases} \dfrac{\sigma}{128} & \text{for } \sigma \leq 64 \\ 1 - \dfrac{\sigma}{128} & \text{otherwise} \end{cases} \qquad (2)$$

72 where σ is the standard deviation. A region is considered to have enough contrast when
73 0.25 ≤ σ_n ≤ 0.5. For, σ_n < 0.25, the region has poor contrast and σ_n > 0.5, the region has
74 too much contrast [21] [22].
75
76 **2.3 Normalized sharpness parameter**

77 Sharpness (*s*) is directly proportional to the high frequency content of an image and is given
78 as,

* Tel.: +91 9419200267
E-mail pklehana@gmail.com.

79 $$s = \sqrt{\| h \otimes I \|}^{2} \qquad (3)$$

80 where h is a high pass filter obtained from the inverse discrete Fourier transform (IDFT)

81 $$h = \text{IDFT}\left(1 - exp\left(-\frac{v_1^2 + v_2^2}{\sigma^2} \right) \right) \qquad (4)$$

82 <mark>where v_1 and v_2 are the spatial parameters. Here, σ is the parameter at which attenuation</mark>
83 <mark>coefficient is considered less than</mark> 1. A smaller value of σ implies that fewer frequencies are
84 attenuated and vice versa. The parameter I represents the given image [21] [22].
85

2.4 Image quality factor

87 The parameters σ_n, μ_n, and s are used for evaluating the image quality or quality factor (Q)
88 defined as

89 $$Q = 0.5\mu_n + \sigma_n + 0.1s \qquad (5)$$

90 where the value of Q lies between 0 and 1. <mark>When Q > 0.55, the quality is considered to be</mark>
91 <mark>good and is poor for Q <= 0.5</mark>. The quality of an image expresses the hidden details in the
92 image. An image is considered as good only if the good regions in the image are more than
93 60% [15].
94

3. METHODOLOGY

96 The lighting conditions from dawn to dusk
97 and the orientation of the sun with respect to
98 the image affect the quality of the captured
99 images. The quality assessment of digital
100 images in an open-air environment under the
101 impact of natural light (non -uniform source of
102 energy) is little complicated. For investigating
103 the effect of diurnal changes and orientation,
104 the images were taken with a 9.1 mega pixel
105 digital camera after regular intervals of 1 hour
106 from sunrise to sunset under the clear vision
107 of natural light. Simultaneously, the images
108 were also taken from four different directions
109 (East, West, North, and South).

110 The steps involved for the investigations are
111 shown in Fig. 1. The images were resized
112 and 100 sub images (each of size 10×10
113 pixels) were constructed. To reduce the bias,
114 each sub image was constructed by selecting
115 100 random pixels from the given image. The
116 quality factor for each sub image was
117 estimated. On the basis of preliminary
118 investigations it was found that equation (5)
119 may be slightly modified by attaching a
120 weighting factor of 0.6 to the normalized
121 contrast (σ_n). The overall quality of the
122 image was estimated by taking the mean of
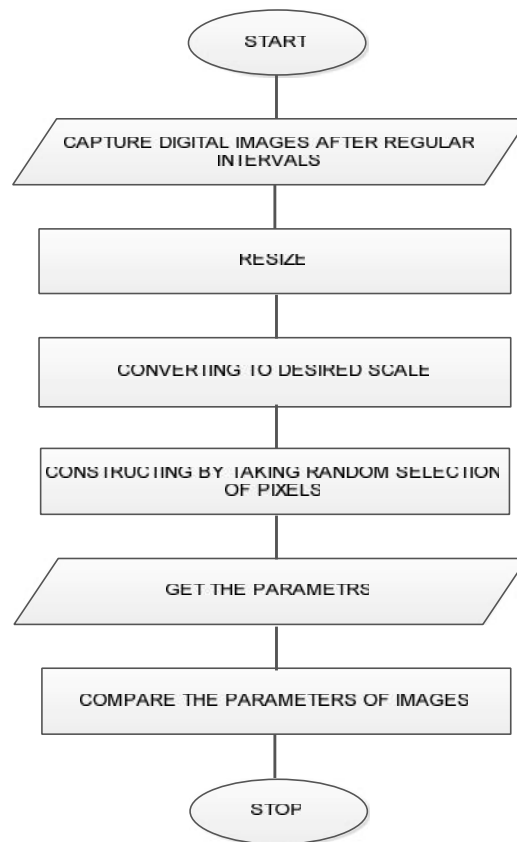123 all the quality factors. One set of four images

Fig. 1. Steps used for the investigations.

* Tel.: +91 9419200267
E-mail pklehana@gmail.com.

124 taken early morning is shown in Fig. 2 to Fig. 5. The same set of images was taken after
125 regular time intervals of 1 hour till the time of sunset on 22nd March, 2013 at Jammu. A total
126 of 13 sets were from 6:50 am to 6:50 pm. These images were resized to 512 x 512 pixels.
127 The effect of diurnal changes was observed for each primary color (color red, green, and
128 blue) and grey scale image.
129
4. RESULTS AND DISCUSSIONS
131 The analysis of the quality of images was carried out with respect to time and orientation.
132 The images were taken with a single camera; however a three legged stand was used for
133 capturing the images. The camera was tightly attached to the stand so that image should be
134 captured at the same angle. Only one camera was used and at one time in one direction
135 only one image was taken. For convenience, the results are presented under the following
136 four sub sections.
137
4.1 Analysis with respect to East
139 The estimated means and the standard deviations of sub images in East direction are listed
140 in Table I and plotted in Fig. 6. All the components images for Red, Green, Blue, and Grey
141 show a high quality image at around 12:50 and poor quality image at 18:50 except for the
142 non-clear blue at 6:50. The average value for the quality of images stands at 0.43, 0.44,
143 0.45, and 0.44 for red, green, blue, and grey images, respectively.
144
4.2 Analysis with respect to West
146 The estimated means and the standard deviations of sub images in West direction are listed
147 in Table II and plotted in Fig. 7. The quality of images falls from 6:50 to 7:50 for all colours
148 and shows an irregular pattern till 10:00. The high quality images were obtained around
149 13:50 for red and grey whereas for green and blue at 15:50. Except for the blue, the poor
150 quality images are obtained around 9:50. The average value of quality comes around 0.43,
151 0.45, 0.45, and 0.45 for red, green, blue, and grey component, respectively. The average
152 value for all the components stands around 0.44. The highest quality image is obtained for
153 blue at around 13:50. Among all the four colors, the blue component shows good results
154 followed by green, grey, and red.

4.3 Analysis with respect to North
156 Mean and the standard deviation of the quality factors of sub images for North direction are
157 listed in Table III and plotted in Fig. 8. The quality is better around 8:50 and poor at 18:50.
158 Red component becomes more prominent after sunrise. This effect neutralizes as the sun
159 moves to noon. The quality of image deteriorates after noon and reaches to a minimum
160 value after sunset. For red component, the average value of the quality of image lies around
161 0.43. For green component, the quality of image is highest around 8:50 and lowest around
162 17:50. The average value lies around 0.44. In comparison to red, quality of green component
163 is relatively better. The minimum value of quality for red falls to 0.36 where as it stays around
164 0.40 for green. The effect on the quality for blue is more pronounced for all images as
165 compared to the other components. The highest value is observed at 18:50 and the lowest
166 at around 17:50. The average value lies around 0.44. After sunset the light in atmosphere
167 shifts to blue and thus the quality of images shoots up. For grey-scale, good quality image is
168 obtained at around 8:50 and the quality deteriorates to the minimum value around 18:50
169 though the average value sustains at 0.43. The quality curves of grey and green show
170 almost similar pattern. The maximum and min value for the two are almost the same. The
171 quality of images from 6:50 to 8:50 does not show any strong variation for any of the color
172 component. The best quality is obtained at around 8:50 in the morning for all the colors
173 except blue for which the highest quality is obtained at 18:50 due to the fact that the sky

* Tel.: +91 9419200267
E-mail pklehana@gmail.com.

174   scatters more blue light just after sunset. The red and green component shows a reverse
175   behavior at 18:50, the blue shows a high quality image whereas the red one shows a poor
176   quality image. Of all the four components, the average quality of blue remains slightly better.
177

178 **4.4 Analysis with respect to South**

179   Mean and the standard deviation of quality factors of sub images for South are listed in
180   Table IV and plotted in Fig. 9. The quality of image for red component is highest around
181   13:50 and poorest around 18:50. The average quality of image lies around 0.44. The quality
182   factor for red increases as the sun rises and attains its maximum value around 13:50 and
183   thereafter a decrease in quality is noticed. Before sunset, the quality of red images shows a
184   slight improvement as compared to other component colors. After sunset, the quality falls to
185   a minimum value. The effect of green and grey components is almost same. The high quality
186   image is obtained around 13:50 and poor quality around18:50. The average quality for grey
187   and green is around 0.45. The effect of on blue is slightly more than other components. The
188   highest quality is obtained at 18:50 and poorest at 17:50. The average quality lies around
189   0.45. For all the components, high quality image is obtained for blue and poor for red.
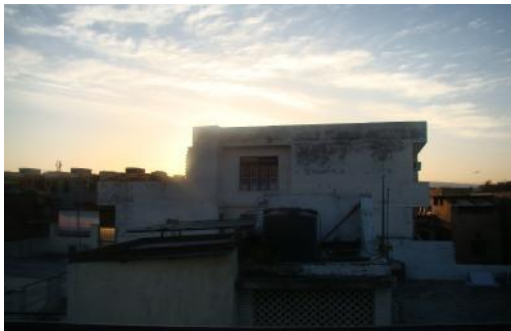190

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192 **Fig. 2. Image taken in East direction.**   **Fig. 3. Image taken in West direction.**
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195 **Fig. 4. Image taken in North direction.**   **Fig. 5. Image taken in South direction.**
196

197   The quality for different components is plotted in Fig. 10 to Fig. 13. The quality of red images
198   is highest in West direction at 13:50 and lowest in East at 18:50. The average value of red
199   component stands at 0.43, 0.43, 0.43, 0.44 for East, West, North, and South, respectively.
200   The average quality for green is around 0.44, 0.45, 0.44, 0.45, for East, West, North, and
201   South, respectively. The quality of blue is high in West around 15:50 and lowest in West
202   around 17:50. The average quality of blue is 0.45, 0.45, 0.44, 0.45 in East, West, North, and
203   South, respectively. It is highest and lowest in West around 13:50, and 9:50, respectively.
204   The average quality for grey is around 0.44, 0.45, 0.43, 0.45, in East, West, North, and
205   South, respectively.

* Tel.: +91 9419200267
E-mail pklehana@gmail.com.

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Table I. Mean quality and standard (SD) deviation in East.

Time	Red		Green		Blue		Gray	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
06:50	0.409	0.004	0.416	0.004	0.408	0.004	0.413	0.003
07:50	0.407	0.003	0.425	0.003	0.429	0.004	0.420	0.003
08:50	0.426	0.002	0.448	0.002	0.450	0.003	0.442	0.002
09:50	0.453	0.003	0.460	0.004	0.456	0.003	0.458	0.003
10:50	0.440	0.002	0.453	0.002	0.453	0.003	0.449	0.002
11:50	0.450	0.002	0.461	0.002	0.462	0.003	0.458	0.003
12:50	0.476	0.003	0.482	0.003	0.477	0.003	0.479	0.003
13:50	0.458	0.002	0.463	0.003	0.460	0.003	0.461`	0.002
14:50	0.454	0.002	0.458	0.002	0.450	0.003	0.455	0.002
15:50	0.439	0.002	0.444	0.002	0.438	0.003	0.442	0.002
16:50	0.421	0.002	0.428	0.002	0.422	0.003	0.426	0.002
17:50	0.404	0.002	0.412	0.002	0.413	0.003	0.410	0.002
18:50	0.334	0.002	0.403	0.002	0.470	0.003	0.391	0.002

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Table II. Mean quality and standard deviation (SD) in West.

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Time	Red		Green		Blue		Gray	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
06:50	0.419	0.003	0.443	0.003	0.455	0.003	0.437	0.002
07:50	0.371	0.002	0.405	0.002	0.432	0.003	0.396	0.002
08:50	0.393	0.002	0.419	0.002	0.445	0.003	0.413	0.002
09:50	0.345	0.001	0.393	0.002	0.431	0.002	0.383	0.002
10:50	0.396	0.002	0.426	0.002	0.453	0.003	0.419	0.002
11:50	0.421	0.002	0.448	0.003	0.472	0.003	0.442	0.003
12:50	0.466	0.003	0.485	0.003	0.497	0.003	0.479	0.003
13:50	0.493	0.003	0.496	0.029	0.463	0.052	0.501`	0.003
14:50	0.479	0.003	0.490	0.004	0.493	0.004	0.486	0.003
15:50	0.485	0.003	0.498	0.003	0.502	0.003	0.493	0.003
16:50	0.464	0.003	0.478	0.003	0.485	0.003	0.474	0.003
17:50	0.433	0.003	0.446	0.003	0.391	0.003	0.443	0.003
18:50	0.377	0.002	0.449	0.003	0.392	0.003	0.436	0.002

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* Tel.: +91 9419200267
E-mail pklehana@gmail.com.

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Table III. Mean quality and standard deviation (SD) in North.

Time	Red		Green		Blue		Gray	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
06:50	0.410	0.003	0.425	0.003	0.425	0.004	0.420	0.003
07:50	0.412	0.003	0.423	0.003	0.424	0.003	0.419	0.003
08:50	0.462	0.002	0.474	0.002	0.469	0.003	0.470	0.002
09:50	0.420	0.002	0.440	0.002	0.452	0.003	0.436	0.002
10:50	0.449	0.002	0.451	0.002	0.445	0.002	0.450	0.002
11:50	0.432	0.002	0.451	0.002	0.455	0.002	0.447	0.002
12:50	0.455	0.002	0.457	0.003	0.444	0.002	0.455	0.003
13:50	0.443	0.002	0.444	0.002	0.436	0.003	0.443	0.003
14:50	0.425	0.003	0.432	0.003	0.427	0.003	0.429	0.003
15:50	0.430	0.003	0.432	0.003	0.425	0.003	0.431	0.003
16:50	0.427	0.003	0.432	0.003	0.424	0.003	0.429	0.003
17:50	0.403	0.002	0.410	0.002	0.412	0.003	0.408	0.002
18:50	0.361	0.002	0.417	0.003	0.476	0.003	0.407	0.003

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Table IV. Mean quality and standard deviation (SD) in South.

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Time	Red		Green		Blue		Gray	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
06:50	0.413	0.004	0.430	0.003	0.429	0.003	0.425	0.003
07:50	0.430	0.002	0.449	0.003	0.448	0.004	0.443	0.004
08:50	0.446	0.003	0.459	0.003	0.460	0.003	0.455	0.003
09:50	0.446	0.003	0.464	0.004	0.461	0.004	0.458	0.004
10:50	0.455	0.004	0.462	0.004	0.451	0.003	0.458	0.003
11:50	0.433	0.003	0.445	0.003	0.441	0.004	0.441	0.003
12:50	0.442	0.003	0.452	0.003	0.446	0.004	0.449	0.003
13:50	0.472	0.003	0.472	0.003	0.455	0.003	0.470`	0.003
14:50	0.449	0.003	0.453	0.003	0.436	0.003	0.450	0.003
15:50	0.455	0.002	0.458	0.003	0.443	0.003	0.455	0.003
16:50	0.441	0.003	0.442	0.003	0.429	0.002	0.440	0.003
17:50	0.451	0.002	0.446	0.003	0.429	0.003	0.445	0.002
18:50	0.348	0.002	0.412	0.003	0.479	0.003	0.400	0.002

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* Tel.: +91 9419200267
E-mail pklehana@gmail.com.
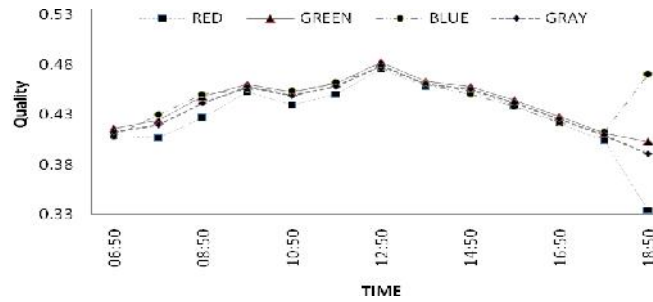
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240   **Fig. 6. Quality versus time plot in East.**

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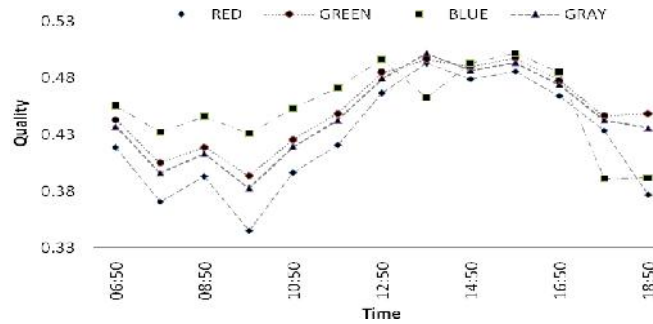242   **Fig. 7. Quality versus time plot in West.**
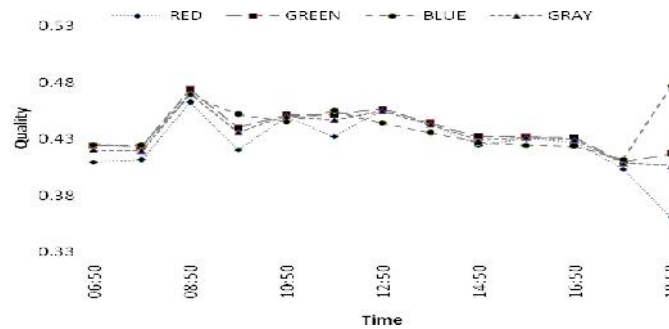
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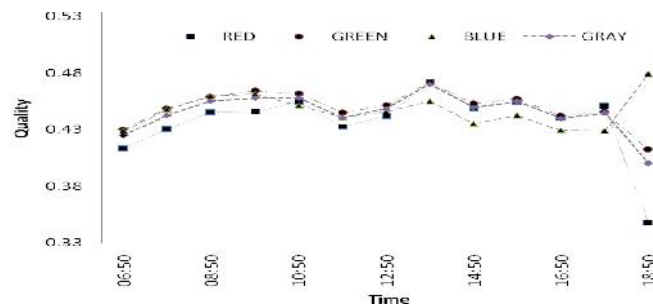244   **Fig. 8. Quality versus time plot in North.**

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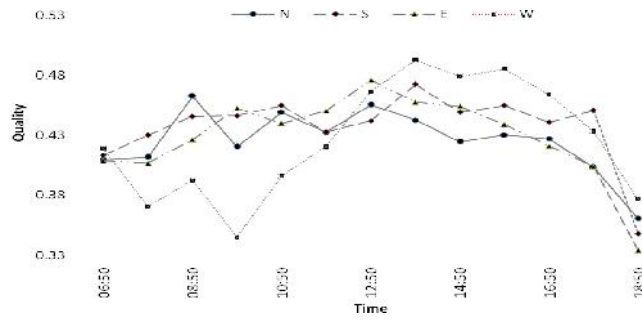246   **Fig. 9. Quality versus time plot in South.**

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* Tel.: +91 9419200267
E-mail pklehana@gmail.com.

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Fig. 10. Quality versus time plot for red.

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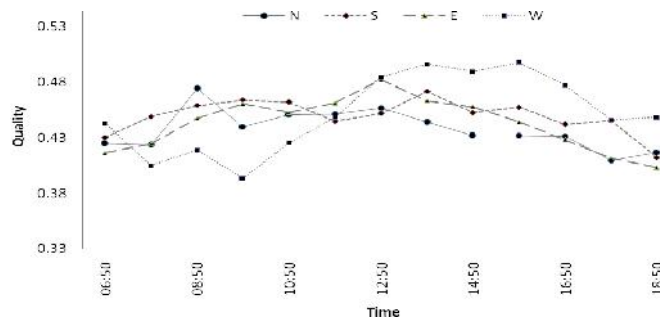
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Fig. 11. Quality versus time plot for green.

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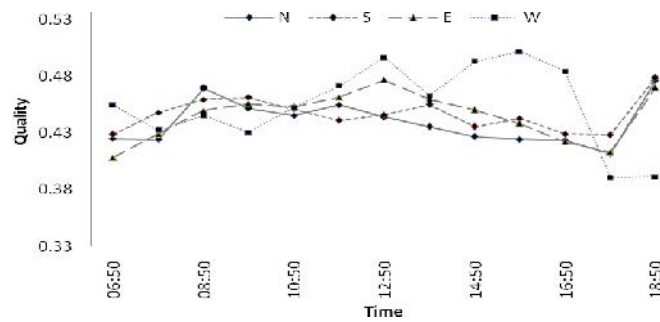
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Fig. 12. Quality versus time plot for blue.

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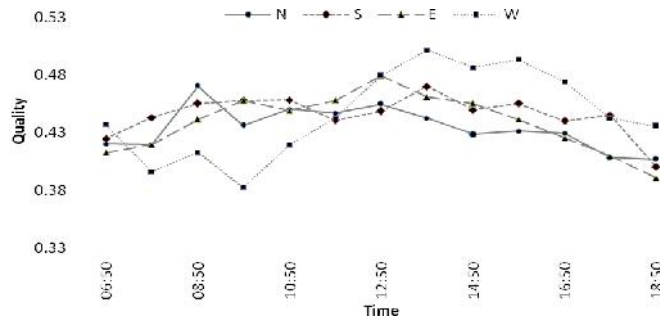
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Fig. 13. Quality versus time plot for grey.

* Tel.: +91 9419200267
E-mail pklehana@gmail.com.

5. CONCLUSION

Analysis has shown that the behavior of red, green, blue, and grey component is the same in all directions except for the blue in West direction. The blue component provides good quality at 18:50 except in West direction. It has been observed that West orientation has considerable effect on the quality of the images. Hence, experienced photographers try to align their camera along this direction for quality imaging.

The investigations were carried out to examine the effect of diurnal changes and orientation of sun on the objective quality of the digital images. The images were taken at regular time intervals of one hour in four directions. Images were little blurred and noisy during the sunrise and sunset. Comparison of objective and subjective quality is on the plan for future work.

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* Tel.: +91 9419200267
E-mail pklehana@gmail.com.

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* Tel.: +91 9419200267
E-mail pklehana@gmail.com.