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Comparison of Statistical Methods for Obtaining Image from Video Frames Based on Development of Quality Metric

Murat Alparslan GUNGOR*[1]

Abstract

Digital images obtained from the video frames have an important role in different areas. Many image processing techniques have been applied to digital images for different purposes such as edge detection. For a better image processing application, it is very important to obtain images with less oscillation from the video. However, the factors such as camera and environment cause differences among the consecutive frames. These differences cause images with oscillation. Statistical methods can be used to obtain images with less oscillation from multiple frames. In this paper, we developed a quality metric to compare the frames or images in accordance with the quantity of oscillation. A comparative study of statistical methods used to obtain the images with less oscillation from the video frames was presented. Images were obtained by using four statistical methods for the different numbers of frames. This study also focuses on evaluating how the statistical method choice affects the oscillation of images using the proposed quality metric and comparing the processing times of the methods.

Keywords: Video frame, statistics, image quality assessment

1. INTRODUCTION

Today, many researchers are analyzing videos for their researches [1]. Video is considered as the collection of frames. Digital images obtained from the video frames are used for many applications. However, such encountered factors as the environment, transmission channels and imperfections in the video acquisition system – especially due to cheap cameras– cause a decrease in image quality [2, 3]. To date, many techniques have been developed to improve video quality. The techniques proposed by Jasmine and Annadurai [4] introduced the particle optimization with adaptive cumulative distribution based on histogram enhancement technique (PACDHE); Okuhata et al. [5] proposed a novel adaptive real-time video image enhancement based on a variational model of the Retinex theory; Tan et al. [6] improved the denoising capability of pixel similarity weighted frame averaging (PSWFA); Anbarjafari et al. [7] proposed a new video resolution enhancement

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technique using wavelet transform and an illumination compensation technique; Singh et al. [8] introduced a novel framework for speckle noise removal and contrast enhancement of real ultrasound videos. These are some of the techniques used to improve the video quality. Each technique has its own feature to improve the video images.

The performance of a technique is evaluated by using the quality metrics. In this paper, we proposed a quality metric to measure the differences between consecutive frames of the same scene without movement because the above-mentioned problems also cause differences between consecutive frames. Measuring these differences is very important for image processing applications. The images with less oscillation give better results for image processing applications. For instance, a researcher uses the edge detection algorithm to find the differences between two objects. The researcher obtains the images of the first and second objects respectively. If one of the above-mentioned problems is encountered, i.e., if there are differences between consecutive frames of the same scene without movement, the fake differences can be seen between the images of objects after the edge detection algorithm. Thus, the accuracy of the algorithm is reduced. In the light of this example, less oscillation between frames means a better edge detection algorithm.

As mentioned above, some factors cause differences between consecutive frames. In this paper, the effect of light on the image was analyzed with the proposed metric. Different statistical methods were used to reduce the differences between the images obtained from the consecutive frames. Four statistical methods were applied to obtain images with less oscillation from the frames. The developed quality metric was used to measure the oscillation between the obtained images. The effects of the light, frame number and method on the oscillation between the images were analyzed. Then, the effect of image complexity on oscillation was studied. Finally, the processing times of the methods were compared.

This paper is organized as follows. In Section 2, an overview of the statistical methods is given. The developed quality metric is explained in Section 3 and its performance is discussed in Section 4. Finally, the conclusions are presented in Section 5.

2. STATISTICAL METHODS

We used four statistical methods: arithmetic mean [9], geometric mean [10], harmonic mean [11], and median [10]. These methods are very popular in many image and video processing applications such as denoising [12], text detection in video frames [13, 14], coding and transmission for conversational HD video service [15]. In this paper, we used these methods to obtain images with less oscillation from the video frames.

The arithmetic mean method determines the value of a pixel in the obtained image as follows:

$$O(x,y) = \frac{\sum_{i=1}^{k} f_i(x,y)}{k} \quad (1)$$

where (x, y) represents the coordinates of the pixel, k is the number of frames, O (x, y) and f (x, y) are the pixel values at the (x, y) coordinates of the obtained image and frame, respectively. Equation (1) is repeated to determine the values of all pixels in the obtained image.

For other methods, the same procedure is repeated except Equation (1). Instead of Equation (1), Equation (2), Equation (3) and Equation (4) are used in geometric mean, harmonic mean and median methods, respectively.

$$O(x,y) = (f_1(x,y) f_2(x,y) f_3(x,y) \ldots f_k(x,y))^{\frac{1}{k}} \quad (2)$$

$$O(x,y) = \frac{k}{\sum_{i=1}^{k} \frac{1}{f_i(x,y)}} \quad (3)$$

$$O(x,y) = \text{median}\{f_1(x,y), f_2(x,y), f_3(x,y), \ldots f_k(x,y)\} \quad (4)$$

While these methods are applied to a group of pixels on an image for conventional image processing applications such as noise reduction, in this paper we applied these methods to pixels that have the same coordinates in different frames.

3. DEVELOPED QUALITY METRIC

In this study, we developed a quality metric to compare the frames or images according to the amount of oscillation. The more above-mentioned problems are encountered, the greater the difference between the consecutive frames of the same scene without movement will be. As a result, more oscillation between the digital images obtained from these frames is created. The aim is to obtain images with less oscillation. The developed metric, Oscillation Assessment Index between Images or Frames (OAIBIF), uses the variance between the images or frames because the maximum oscillation occurs in the maximum variance. OAIBIF metric is defined as follows:

$$\text{OAIBIF} = \left(\frac{\text{mean variance}}{\text{maximum variance}}\right).\text{SP} \quad (5)$$

where SP is defined as the sensitivity parameter. This parameter is determined by the user to achieve the most sensitive results. To calculate the OAIBIF metric for the images or frames of sizes of m * n, first, the variances between pixels with the same coordinates in different images or frames are calculated. Thus, for the images or frames of sizes of m*n, m*n variances are obtained. Equation (6) is used to calculate the mean variance in Equation (5).

$$\text{mean variance} = \frac{[\text{variance }(1,1) + \text{variance }(1,2) + \cdots + \text{variance }(2,1) + \text{variance }(2,2) + \cdots + \text{variance }(m,n)]}{m*n} \quad (6)$$

where variance (1,1), variance (1,2) … and variance (m, n) are defined as variances between the pixels whose coordinates are (1,1), (1,2) … and (m, n), respectively.

The maximum variance in Equation (5) for the different number of images or frames is shown in Table 1.

Table 1
The maximum variance for different number of images or frames

Number of images or frames	The maximum variance
3	21675
4	21675
5	19507.5
6	19507.5
7	18578.57143
8	18578.57143
9	18062.5
10	18062.5
11	17734.09091
12	17734.09091
13	17506.73077
14	17506.73077
15	17340

The minimum and maximum values of the pixel are considered to calculate the maximum variance. For example, for seven images, the maximum variance value is calculated for four 0 and three 255 pixel values.

Larger OAIBIF indicates the images or frames with more oscillation. If OAIBIF is equal to zero, this means that there is no difference between consecutive images or frames, the camera has excellent performance and the above-mentioned problems do not affect the images or frames. If the mean variance is equal to maximum variance, then there is too much difference between consecutive images or frames of the same scene without movement.

4. RESULTS AND DISCUSSION

We used the experimental setup shown in Figure 1 to obtain the consecutive frames.

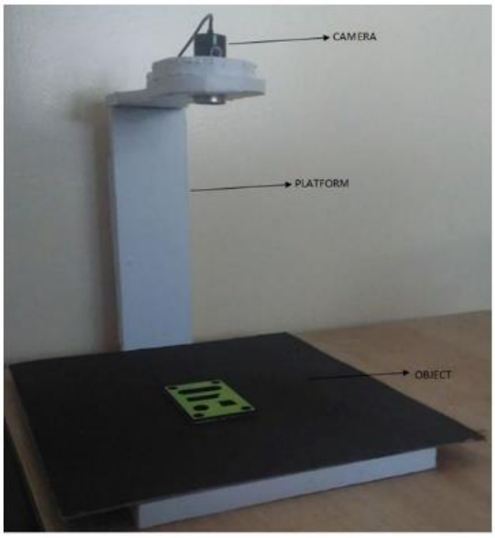


Figure 1 The experimental setup used in the study

Our experimental setup has three parts: a camera, platform, and object. The images of the object were obtained from the camera with the Matlab program and the program is shown in Figure 2.

Figure 2 Screenshot of image obtainment with the camera

We obtained one hundred and fifty frames for each application. These frames were divided into groups of fifteen. One or more frames in each group were used to form an image. To obtain the frames, "Take Frames" button shown in Figure 2 is used. When the "Take Frames" button is clicked, the processing time is very short. This means that the time duration from acquiring the first frame of the first image to the last frame of the last image is short. The aim is to ensure that there is no difference between the frames by keeping the time duration very short; but the above-mentioned problems affect the frames. The calculated OAIBIF values between the frames for an application are shown in Table 2.

Table 2
OAIBIF values between the frames for each image

	OAIBIF
for image 1	3.589054258
for image 2	3.569613997
for image 3	3.461656048
for image 4	3.550260042
for image 5	3.473456519
for image 6	3.511795775
for image 7	3.564171021
for image 8	3.518609685
for image 9	3.504872528
for image 10	3.55007135

Table 2 shows OAIBIF values between the fifteen frames for each image. In this study, the value of SP shown in Equation (5) was selected as 10000. For excellent performance, the value of OAIBIF is desired to be zero. If Table 2 is analyzed, it can be seen that the values of OAIBIF between the frames are about 3.5; meaning that the above-mentioned problems affect the frames.

Digital images are obtained from the video frames. This process is random. In this paper, instead of performing a random process, a group of fifteen frames was created for each image. When an image was to be obtained using a single frame from each group, the first frame in each group was selected. Thus, 10 images for 10 groups were obtained. Then, images were obtained using the different number of frames - k=3,7,11,15- and four statistical methods - arithmetic mean, geometric mean, harmonic mean and median- to reduce the oscillation between images. For example, if an image is obtained from three frames using the arithmetic mean method, the first three frames in the group are taken into account. Ten images were obtained for each number of frame and statistical method. Table 3 shows OAIBIF values between the images obtained by using the different number of frames and methods.

Table 3
OAIBIF values between the images for different number of frames and methods

Number of Frames and Method	OAIBIF
k=1	3.525118949
k=3, arithmetic mean method	1.318378861
k=3, geometric mean method	1.326692989
k=3, harmonic mean method	1.345553437
k=3, median method	1.315705976
k=7, arithmetic mean method	0.667631561
k=7, geometric mean method	0.674031323
k=7, harmonic mean method	0.690851358
k=7, median method	0.699185843
k=11, arithmetic mean method	0.456831202
k=11, geometric mean method	0.462280189
k=11, harmonic mean method	0.475101222
k=11, median method	0.489580957
k=15, arithmetic mean method	0.352821858
k=15, geometric mean method	0.357759934
k=15, harmonic mean method	0.367979849
k=15, median method	0.382907986

As shown in Table 3, the value of OAIBIF between ten images obtained for k = 1 is 3.525. The different number of frames and statistical methods were used to reduce this value. When Table 3 is analyzed, it is observed that the OAIBIF value decreases as the frame number increases. While the result obtained from the median method is slightly better than the result obtained from the arithmetic mean method for k=3, the arithmetic mean method gives the best results for higher values of k for the first application.

The OAIBIF values between the images shown in Table 3 depend on the OAIBIF values between the frames shown in Table 2. Using the same camera, platform and object, we performed another application. The results of the second application are shown in Table 4 and Table 5.

Table 4
For the second application, OAIBIF values between the frames for each image

	OAIBIF
for image 1	3.190312897
for image 2	3.186761742
for image 3	3.200678401
for image 4	3.20506631
for image 5	3.184293296
for image 6	3.169900469
for image 7	3.166245347
for image 8	3.177909462
for image 9	3.17651831
for image 10	3.172085197

Table 5
For the second application, OAIBIF values between the images for different number of frames and methods

Number of Frames and Method	OAIBIF
k=3, arithmetic mean method	1.088438566
k=3, geometric mean method	1.092957229
k=3, harmonic mean method	1.105049987
k=3, median method	1.081353732
k=7, arithmetic mean method	0.509540425
k=7, geometric mean method	0.512815249
k=7, harmonic mean method	0.523121221
k=7, median method	0.533838721
k=11, arithmetic mean method	0.351981108
k=11, geometric mean method	0.354413779
k=11, harmonic mean method	0.362532798
k=11, median method	0.378225662
k=15, arithmetic mean method	0.277658029
k=15, geometric mean method	0.279574858
k=15, harmonic mean method	0.2860909
k=15, median method	0.302458874

Comparing Table 2 and Table 4, the amount of oscillation between the frames obtained in the second application is less than the amount of oscillation between the frames obtained in the first application. As a result, Table 3 and Table 5 are compared, it is shown that the images obtained in the second application have less oscillation than the images obtained in the first application. Table 5 shows that while the very close results of the arithmetic mean and median methods are the best results for k=3, the arithmetic mean method is the best method among the four methods to reduce the oscillation between the images for higher values of k, as in the first application.

One of the problems affecting the oscillation between the images is the effect of light. In this study, we performed three applications -third, fourth and fifth applications- to analyze the effect of light on oscillation. In these applications, the fifth application has the brightest environment, while the third application has the least bright environment. OAIBIF values between the frames for the third, fourth and fifth applications are shown in Table 6.

Table 6
For the third, fourth and fifth applications, OAIBIF values between the frames for each image

	OAIBIF for		
	the third application	the fourth application	the fifth application
for image 1	0.531858708	2.261232577	3.025993026
for image 2	0.528763299	2.268105204	3.014552717
for image 3	0.525337575	2.13092498	3.014812282
for image 4	0.527548782	2.187285716	3.027073588
for image 5	0.527707412	2.18979657	3.023207776
for image 6	0.529436853	2.130556246	3.015490315
for image 7	0.526602452	2.141309735	3.022219283
for image 8	0.54445621	2.192560209	3.018972695
for image 9	0.525800341	2.185371059	3.01752655
for image 10	0.526528894	2.129599413	3.014587508

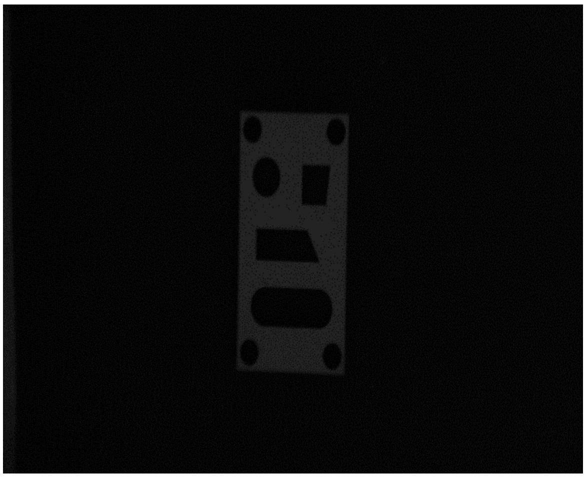
Table 6 shows that more bright environment causes a greater amount of oscillation between the frames. While OAIBIF values are about 0.5 for the third application with the least bright environment, OAIBIF values are about 3 for the fifth application with the brightest environment. The images with the highest oscillation are obtained from the fifth application as shown in Table 7.

Table 7
For the third, fourth and fifth applications, OAIBIF values between the images for different number of frames and methods

	OAIBIF for		
Number of Frames and Method	the third application	the fourth application	the fifth application
k=3, arithmetic mean method	0.20789316	0.765139939	1.011931214
k=3, geometric mean method	0.21333897	0.763563836	1.013906202
k=3, harmonic mean method	0.220275313	0.769359909	1.018262637
k=3, median method	0.242142202	0.948115851	0.961466518
k=7, arithmetic mean method	0.114512857	0.359958343	0.465117995
k=7, geometric mean method	0.120120805	0.360405159	0.466137095
k=7, harmonic mean method	0.127880561	0.36461776	0.469996057
k=7, median method	0.133036902	0.478495225	0.459825836
k=11, arithmetic mean method	0.085669837	0.268136341	0.315076324
k=11, geometric mean method	0.09262416	0.268963015	0.315831138
k=11, harmonic mean method	0.095315794	0.272629301	0.318677491
k=11, median method	0.098329569	0.35570909	0.318922497
k=15, arithmetic mean method	0.071289613	0.207260595	0.244772046
k=15, geometric mean method	0.078451364	0.208771333	0.245430966
k=15, harmonic mean method	0.081223405	0.211895532	0.247664665
k=15, median method	0.080994457	0.276369585	0.251377186

Table 7 shows that the arithmetic mean method is the best method for the third application with low oscillation frames. For the brighter environment, while the arithmetic mean method is less effective for the smaller number of frames, this method is the best method among methods mentioned in this paper as the number of frames increases. For more bright environments and a smaller number of frames, the median method can be used to have images with low oscillation as shown in the fifth application.

The main scope of this paper is to develop a quality metric to measure the oscillation between the images or frames without movement. After analyzing the effect of light on oscillation, we analyzed the effect of image complexity on oscillation using OAIBIF. To make this analysis, we used two images; basic image and complex image, shown in Figure 3.



(a)

(b)

Figure 3 (a) Basic image (b) Complex image

As shown in Figure 3, the complex image has more objects than the basic image. OABIF values between the frames for the basic and complex images are shown in Table 8.

Table 8
OAIBIF values between the frames for the basic and complex images shown in Figure 3

	OAIBIF for	
	the basic image	the complex image
for image 1	0.264177891	0.610616396
for image 2	0.273002471	0.606499729
for image 3	0.275166205	0.593290857
for image 4	0.281117924	0.570233579
for image 5	0.2536753	0.603319578
for image 6	0.280907443	0.621834299
for image 7	0.278978147	0.623157961
for image 8	0.284807853	0.618820925
for image 9	0.262726809	0.631207604
for image 10	0.287779072	0.592809232

While OAIBIF values between the frames are about 0.6 for the complex image, these values are about 0.27 for the basic image. Table 8 indicates that more image complexity causes higher oscillation between the frames as expected. When the basic and complex images obtained from the frames with the different methods are compared, it is seen that the complex images have higher oscillation than the basic images for all methods as shown in Table 9. Comparing the methods, the arithmetic mean method gives the best results for both the basic and complex images as in previous applications.

Table 9
For the basic and complex images shown in Figure 3, OAIBIF values for different number of frames and methods

	OAIBIF for	
Number of Frames and Method	the basic image	the complex image
k=3, arithmetic mean method	0.137656504	0.227283693
k=3, geometric mean method	0.139932036	0.231430786
k=3, harmonic mean method	0.142562325	0.238988103
k=3, median method	0.149680735	0.272631404
k=7, arithmetic mean method	0.081331162	0.126619403
k=7, geometric mean method	0.082615391	0.130542197
k=7, harmonic mean method	0.085034682	0.136442148
k=7, median method	0.08954046	0.155499102
k=11, arithmetic mean method	0.056900569	0.09681204
k=11, geometric mean method	0.057782053	0.100964218
k=11, harmonic mean method	0.059020403	0.105030167
k=11, median method	0.063103314	0.118166461
k=15, arithmetic mean method	0.049324521	0.08145526
k=15, geometric mean method	0.049868557	0.08530483
k=15, harmonic mean method	0.050267312	0.088548303
k=15, median method	0.05413561	0.098442251

Finally, we compared the processing times of the methods shown in Table 10.

Table 10
The processing time of the methods for different number of frames

	Processing time (sec)			
	arithmetic mean method	geometric mean method	harmonic mean method	median method
k=3	0.600838	0.653749	0.62164	7.22081
k=7	1.398986	1.529841	1.426312	8.40238
k=11	2.33623	2.53114	2.395979	9.400916
k=15	3.339206	3.555974	3.3489842	10.62196

We obtained Table 10 using 480 images. We used 30 images and averaged the sum of the acquisition time of each image for each k and method. Among these methods, while the shortest processing time belongs to the arithmetic mean method, the median method has the longest processing time. As the number of frames increases, processing time increases as expected.

5. CONCLUSIONS

Video is considered as the collection of frames and digital images obtained from the video frames are used for many applications. The differences between the consecutive frames of the same scene without movement affect the accuracy of the applications such as edge detection. Using the developed metric, OAIBIF, the oscillation between the frames or images can be assessed. In this paper, we obtained frames from different bright environments and compared the oscillation between the frames using OAIBIF. Higher oscillation between the frames means higher oscillation between the images. We used multiple frames with different statistical methods to obtain images with less oscillation. Using OAIBIF, we analyzed the oscillation between the obtained images. Significant results are attained from the analysis providing valuable information to obtain the images with the least oscillation. The arithmetic mean method gives the best results for the less bright environments and this method performs in the shortest time among the methods mentioned in this study. Although the processing time of the harmonic mean method is close to the processing time of the arithmetic mean method, the images with less oscillation are obtained with the arithmetic mean method. The geometric mean method gives less favorable results than the arithmetic mean method, both in terms of the processing time and in the performance of reducing oscillation between images. Although the median method reduces oscillation between images more than the arithmetic mean method for the brighter environment and the smaller number of frames, the processing time of the median method is much greater than the arithmetic mean method. As the number of frames increases, problems such as storage may occur. Therefore, if the processing time is not taken into account, the median method can be used for brighter environments and the small number of frames to obtain images with less oscillation. Considering both oscillation reduction performance and the processing time, while the arithmetic mean method is less effective for the smaller number of frames and the brighter environments, this method is the best method among the methods mentioned in this paper as the number of frames increases.

After the effect of light on oscillation, the effect of image complexity on oscillation was analyzed by using OAIBIF. The results show that more image complexity causes a higher oscillation between the frames. As in previous applications, the arithmetic mean method gave the best results for both the basic and complex images presented in this study.

The developed metric, OAIBIF, is used to assess the oscillation between the frames or images. The closer this metric to zero means the frames or images with less oscillation are obtained. Although we analyzed the effects of the light, frame number and method, this metric can be used to analyze the effect of any factor on the oscillation between the frames or images.

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The Declaration of Conflict of Interest/ Common Interest

No conflict of interest or common interest has been declared by the authors.

The Declaration of Ethics Committee Approval

This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics

The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

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