A Quantitative Measure in Uniform Color Space for Dynamic False Contours on PDP

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Abstract

Quantitative analysis of dynamic false contours on PDP is essential to evaluate the performance of algorithms for false contour reduction. It also serves as an optimization criterion for selecting the subfield pattern. In this paper, a color difference in uniform color space is defined as a new measure for dynamic false contours. Unlike the measures in previous works, it accounts for the channel dependencies among the RGB color channels.

1. Introduction

Plasma displays represent the gray levels by the pulse count modulation technique that results in undesirable dynamic false contours on the moving images[1]. Various techniques have been proposed to reduce the dynamic false contours[2,3]. In order to evaluate the performances of the proposed techniques, the degree or severity of the dynamic false contours appeared on the plasma displays should be measured.

This measurement can be achieved by the subjective human visual evaluation or calculating the objective quantitative measure. The human visual evaluation is quite time consuming. Thus, it is desirable to utilize an objective measure that faithfully describes the degree of dynamic false contours perceived by human visual system. Ideal objective measure should generate the same results as the human visual evaluation tests. Another application of the quantitative measure would be its utilization as a minimization criterion for selecting a subfield pattern by optimization techniques such as genetic algorithm [4].

The simplest form of the objective measure would be the mean squared error (MSE) or the signal-to-noise ratio(SNR) proposed in [5]. Although popular for their simplicity, the MSE and SNR do not closely correlate with the results of the human visual evaluation. Recently, a few objective measures for the dynamic false contours have been proposed[6,7].

The dynamic false contours perceived by the human visual system are the differences both in the luminance and chrominance information. However, the quantitative measures proposed in previous works are based only on the luminance information of each of the RGB color channels. When calculating the quantitative measures, the same procedure was applied to each of the RGB channels and combined as a single measure. This process of calculating the quantitative measures dose not account for the chromatic differences and relationship between the RGB color channels.

This paper proposes a new quantitative measure for the dynamic false contours. In the proposed method, the color difference in the uniform color space is defined as a quantitative measure of the dynamic false contours. The uniform color space is designed to account for luminance and chrominance difference perceived by human visual system[8]. In order to calculate color difference in the uniform color space, the RGB color coordinates are transformed to the uniform color coordinates.

In the experiments, the limitation of calculating the dynamic false contours for each of RGB channels is described by an example. In order to evaluate the performance of the proposed measures, human visual test is performed. The results of the proposed measure are compared with the results of human visual tests and those of previously proposed measures.

In section 2, the proposed method is explained in detail. In section 3, the experiments performed are presented and their results are analyzed.

2. Proposed Measure of Dynamic False Contours

The flow chart for calculating the proposed quantitative measure is shown in Figure 1. Each process in Figure 1 is explained next. First, the inverse gamma is applied to an original image chosen for calculation of the quantitative measure. The resulting image represents an image to be ideally displayed on PDP without the dynamic false contours. The PDP simulation[9] is applied to the inverse gamma corrected image. The resulting simulated image represents an image to be actually displayed on PDP with the dynamic false contours caused by the motion vector utilized in the PDP simulation.

Based on the two images, the inverse gamma corrected and PDP simulated images, a quantitative measure is calculated. Two practical problems that might cause the misinterpretation of the calculated measures are considered in advance. First problem is the small changes in RGB values as a result of the PDP simulation. Ideally, the RGB values on the PDP simulated image should be the same as on the inverse gamma corrected image except those areas containing the dynamic false contours. However, the PDP simulation often generates a small change in the RGB values in the area free of the dynamic false contours. For a given original image, a single measure of dynamic false contour is calculated. In other words, color difference for each pixel is summed up to represent a single measure of dynamic false contours on a given image. Thus, when summed up, these small changes in RGB values can be accumulated to a significant value in the quantified measure that may cause misinterpretation. Thus, the threshold values in the RGB coordinates are defined to exclude those pixels having small changes in the RGB values.

Second problem considered before the calculation of the proposed measure is the exclusion of pixels on the edges. It is likely that the dynamic false contours appear on the smooth transition areas, not on the edges on the image. Thus, edges on the original image are detected based on a simple edge operator. Those pixels identified as the edges are excluded in the calculation of the proposed measure.

Once the pixels to be excluded for the calculation of the proposed measure are determined by the two procedures described above, the RGB coordinates of the inverse gamma corrected and PDP simulated images are converted into the coordinates in the uniform color space. The uniform color space is designed so that the color difference including the luminance and chrominance components is proportional to the Euclidean distances in the uniform color space. However, the same argument is not generally true for the RGB color space. The uniform color space selected in this paper is the Lab space. The Euclidean distance is calculated between Lab color coordinates of the inverse gamma corrected and PDP simulated image. It is calculated for each pixel on the image except those pixels chosen in advance not to be included for the calculation of the proposed measure. The calculated Euclidean distances are added up and serve as a proposed measure of the dynamic false contours.

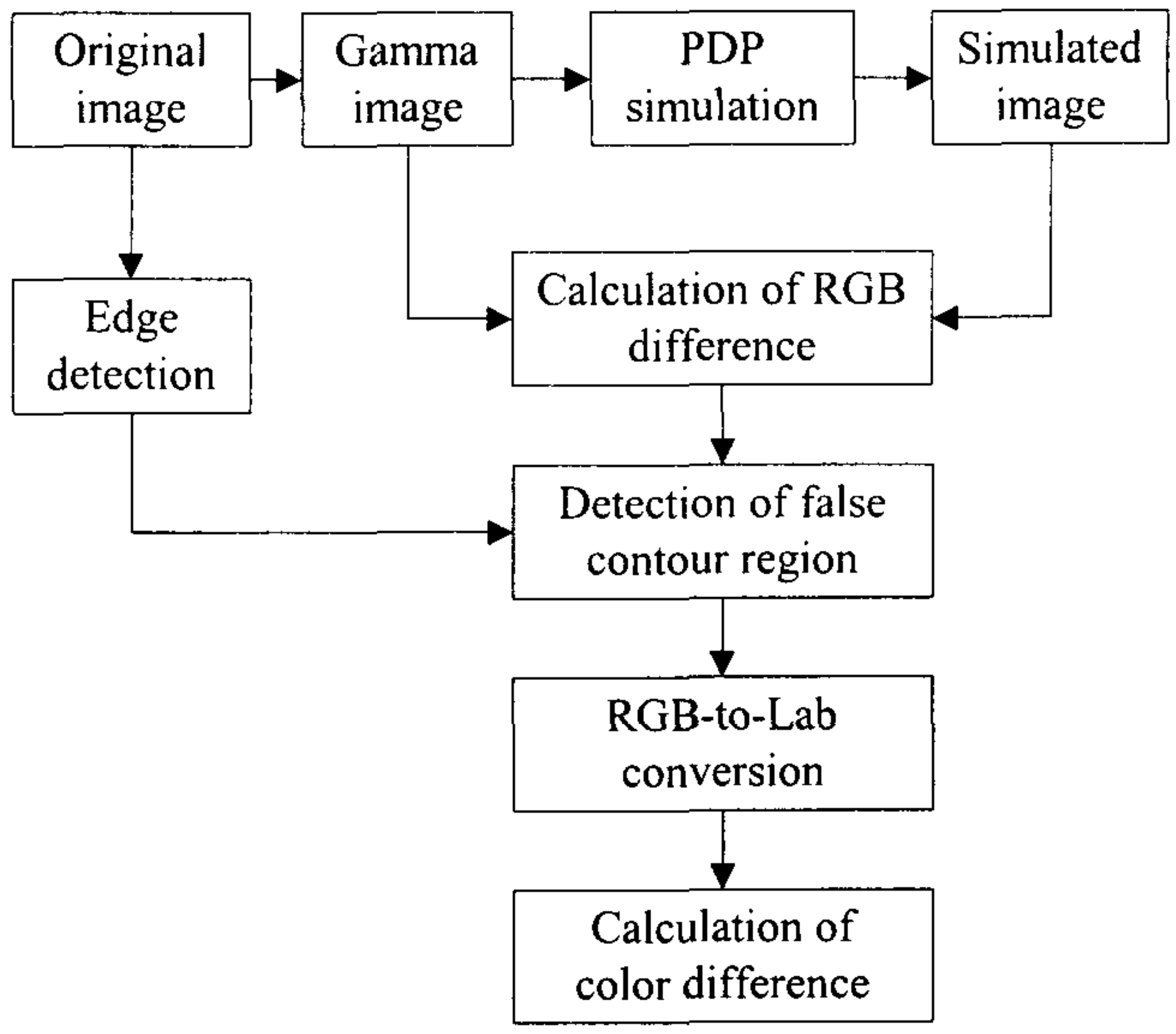

Figure 1. Flow chart of proposed method

3. Experimental Results

Before presenting the experimental results, the limitation of the previous method [6,7] that calculate the quantitative measure for each of the RGB channels independently is described.

Suppose an image whose R and B values are fixed and only G values are gradually changed from 0 to 255. Figure 2 shows such an example. The image shown in Figure 2 is of size 200x512. In Figure 2, R and B are fixed to the gray level of 100. The values of G are changing from 0 to 255. The vertical lines in Figure 2 represent the dynamic false contours.

When calculating the measure of dynamic false contours channel by channel, only G channel would contribute to the quantitative measure because there is no change in the gray levels for the R and B channels. Assume that there is another image whose R and B values are fixed to 255 and G values are changing by the same way as in Figure 2. Even though the fixed values of the R and B channels are changed from 100 to 255, two images would generate the same value of quantitative measure. It is due to the fact that the same procedure for calculating dynamic false contours is applied independently to each of the RGB channels. However, when evaluated on PDP, the degree of dynamic false contours on two images, one image with gradually changing G and R=B=100 and another image with gradually changing G and R=B=255, perceived differently by the human observer.

Figure 3 shows the quantitative measures calculated for the aforementioned two images based on the

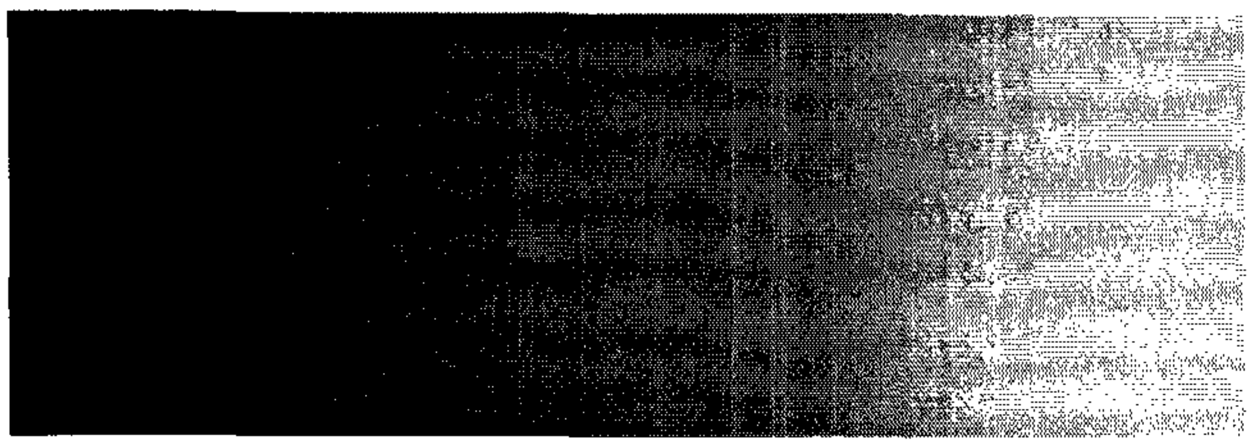

Figure 2. An Example of Simulated Image (G changing from 0 to 255, R=B=100)

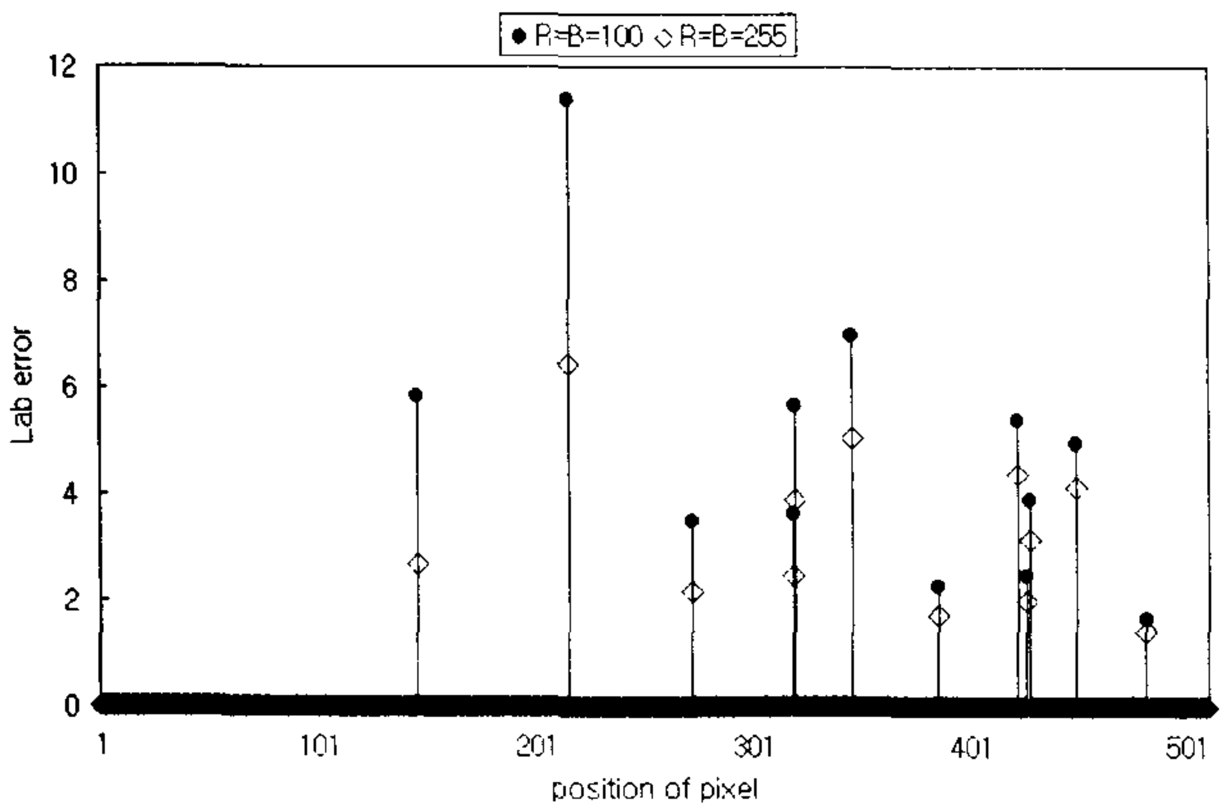

Figure 3. Calculated Measure for each of columns on two G ramp images based on proposed method

proposed method. In Figure 3, the horizontal axis represents horizontal position of the G ramp image as in Figure 2. The vertical axis denotes the calculated measure for the pixels on each column on two G ramp images having different fixed values of R and B. As shown in Figure 3, the proposed measure provides different values of measures unlike the previous method generating the same values for both of G ramp images.

The experiments performed to evaluate the performance of the proposed measure are described next. Test images for the experiments are shown in Figure 4. In order to exhibit different levels of the dynamic false contours, five subfield patterns listed in Table 1 are selected.

Human visual test is performed first. For the test images shown in Figure 4, the moving images having v=4[pixel/frame] in left to right direction are generated. The moving images are displayed on PDP using "windows media player" program. The PDP utilized in the experiment is of 42-inch with 853x480 resolution. The color temperature of white is 6500K, and inverse gamma is corrected with 1.8. Graphic resolution of the moving images on PDP is set to be in 640x480 mode.

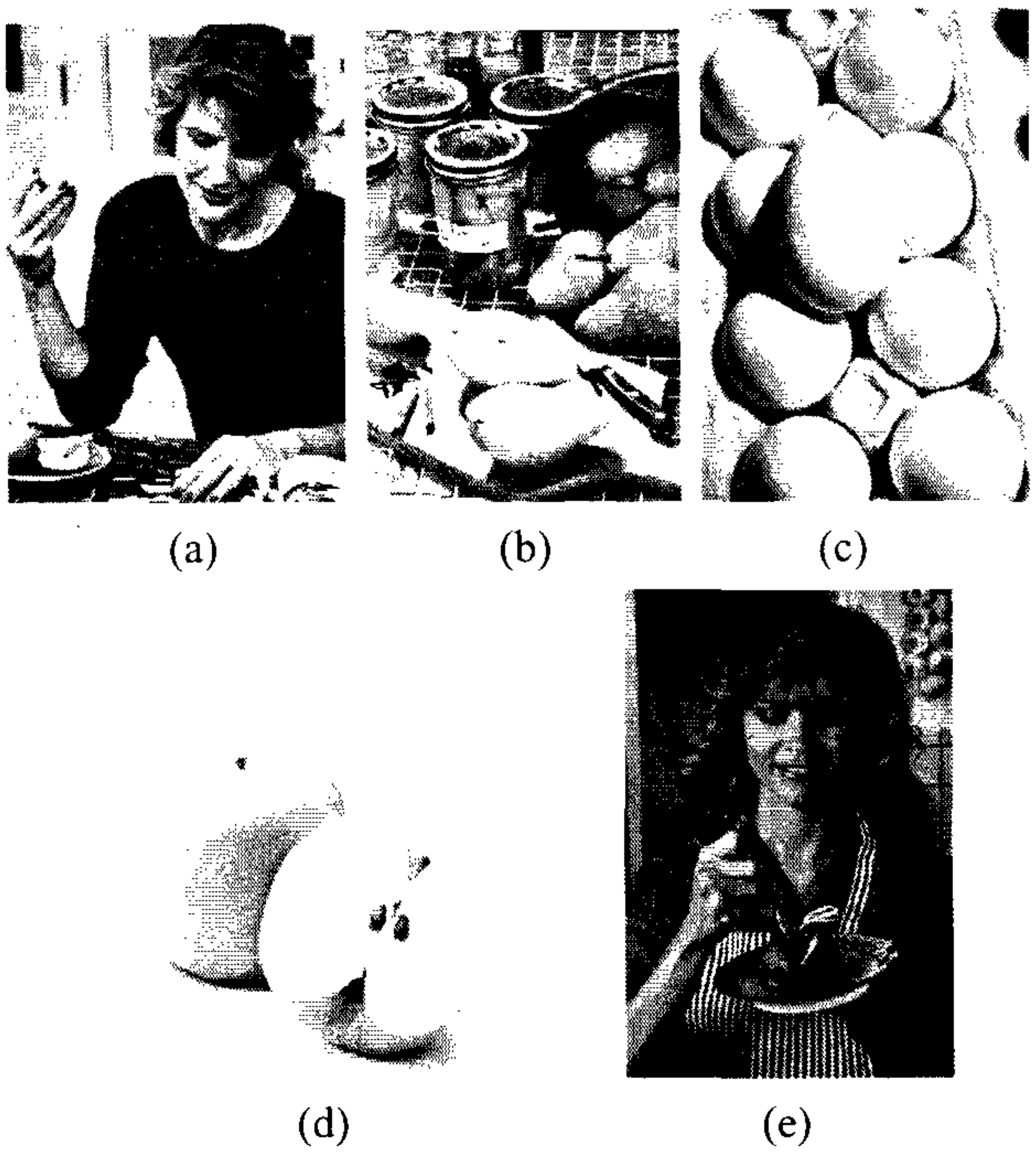

Figure 4. Test images for experiment

(a)Woman1 (b)Kitchen (c)Egg (d)Apple (e)Woman2

Table 1. Subfield patterns for experiment

	Subfield Pattern
SF1	[4 16 20 8 2 36 52 56 60 1]
SF2	[48 48 1 2 4 8 16 32 48 48]
SF3	[1 2 16 8 63 16 19 63 4 63]
SF4	[51 42 14 4 1 2 8 29 45 59]
SF5	[1 2 4 8 14 29 42 45 51 59]

Subjects participating in the visual experiment consist of 3 non-experts and 3 experts for the false contour. For each test image, five moving images with different subfield patterns in Table 1 are shown to subjects. The best image is given point 1. Subjects can choose one of three states, 'better', 'little bit better', and 'same'. The point deviation for each of the above three states are 1, 0.5, and 0, respectively. The points for each moving image are averaged over six subjects.

In addition to the human visual examination, the proposed measure is calculated. Also, the quantitative measured in previous works[6,7] are calculated for comparison. The results of human visual examination and calculated measures are listed in Table 2. In Table 2, first column denotes five subfield patterns in Table 1. Second column is the results of human visual examination. Third column represents the values of the proposed measure. Fourth column marked as 'Choi' is a calculated measure by the method in [6].

Fifth and six columns marked as 'SMSE-1' and 'SMSE-2' are two calculated measures proposed in [7]. The parenthesized number means the final rank.

As shown in Table 2, among the four different measures considered in this experiments, the result of the proposed method provides the best matches with the results of the human visual tests. The method proposed in [6] is better than the method in [7]. But, it is worse than the proposed method, especially in 'Egg' and 'Woman-2' images.

4. Conclusion

This paper proposes a new quantitative measure for the dynamic false contours. In the proposed method, the color difference in the uniform color space is defined as the quantitative measure of dynamic false contours. The proposed measure accounts for the luminance and chrominance difference perceived by human visual system. Experimental indicates that the result by the proposed method provides the best matches with the human visual evaluation.

5. Acknowledgements

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6. References

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Table 2. Comparison of quantitative measures

Woman-1					
	Visual	Proposed	Choi	SMSE-1	SMSE-2
SF1	1.83(2)	86427(2)	774001(2)	23.47(5)	23.93(5)
SF2	3.58(4)	178689(4)	4941901(4)	22.78(4)	22.90(4)
SF3	2.92(3)	131599(3)	1872399(3)	21.19(3)	21.45(3)
SF4	4.58(5)	195577(5)	10889241(5)	19.95(2)	19.91(2)
SF5	1.00(1)	47240(1)	453554(1)	19.15(1)	19.39(1)

Kitchen					
	Visual	Proposed	Choi	SMSE-1	SMSE-2
SF1	2.17(2)	108408(2)	685729(2)	25.79(4)	26.29(4)
SF2	2.75(3)	186183(4)	4370691(4)	29.91(5)	29.69(5)
SF3	3.75(4)	141459(3)	1754263(3)	24.57(3)	24.81(3)
SF4	4.42(5)	232549(5)	12582518(5)	24.36(2)	24.25(2)
SF5	1.17(1)	89113(1)	398039(1)	21.51(1)	21.86(1)

Apple					
	Visual	Proposed	Choi	SMSE-1	SMSE-2
SF1	1.67(2)	37892(3)	142037(2)	11.59(2)	11.82(2)
SF2	3.67(4)	61944(4)	728591(3)	17.67(5)	17.96(5)
SF3	2.42(3)	37867(2)	732801(4)	12.03(3)	12.11(3)
SF4	4.67(5)	115200(5)	5467373(5)	14.09(4)	14.18(4)
SF5	1.42(1)	18088(1)	92621(1)	9.79(1)	9.87(1)

Egg					
	Visual	Proposed	Choi	SMSE-1	SMSE-2
SF1	2.00(2)	118698(2)	529091(2)	22.87(4)	23.11(4)
SF2	3.58(4)	262982(4)	2054544(3)	24.99(5)	25.04(5)
SF3	3.17(3)	122313(3)	3564138(4)	21.30(2)	21.52(3)
SF4	4.25(5)	401270(5)	18586808(5)	21.54(3)	21.50(2)
SF5	1.00(1)	57682(1)	367537(1)	19.18(1)	19.41(1)

Woman-2					
	Visual	Proposed	Choi	SMSE-1	SMSE-2
SF1	2.42(3)	95204(2)	699196(2)	36.53(5)	36.80(5)
SF2	1.42(2)	147245(3)	5966456(4)	31.19(3)	30.75(3)
SF3	4.33(5)	184839(5)	805331(3)	32.54(4)	32.61(4)
SF4	3.33(4)	179230(4)	6939019(5)	29.47(1)	29.16(1)
SF5	1.17(1)	69691(1)	352038(1)	30.51(2)	30.72(2)