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Panoramic Mosaic Conception using Optimal Seam with Graded Colour Correction

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***Abstract*—We propose a duplex methodology for merging a set of aligned source images with exceedingly dissimilar colours and luminance into a composite panorama with amenable blending attributes. The algorithm performs an optimal seam to determine the suture point which consequently is expertly camouflaged using the graded colour blending to create the vista. Exposure leveler is the pedestal on which the dual algorithms are juxtaposed. The individual Y components of each slice are normalized as the direct ratio of the maximum luminance averaged over the brightest source image. The graded colour blending performs a smooth transition over the seam by weighing the pixels colours as an inverse function of the square of the distance from the seam. The technique has been exhaustively verified on divergent image sequences which generate progressively transcendent sutures in both indoor and outdoor scenarios providing comparatively low values of mse (~11.18).**

Keywords*— Panorama; Exposure leveling; Image Stitching; Optimal Seam; Color Blending.

I. INTRODUCTION

Panorama is a perpetual perspective of a singular landscape acquired as a collection of images with differential capturing characteristics of time, focus and location. It is this circumambient distinctiveness of the imagery that each of them is required to be fittingly aligned and then sutured without any irregularities to generate the panoramic brilliance of the original landscape. The progression of stitching encounters exposure, spatial and colour irregularities along the seam of the panorama. Each of these problems has to be individually addressed using exposure leveling, generating seam and colour correction algorithms respectively. Though each of the aforementioned algorithms is detailed exhaustively in literature, a need arises to conjointly provide undemanding solutions to craft a panorama with minimum photometric inconsistencies, few computations and specifically memory requirement pliable to smart phones and digital cameras. Sequentially the exposure artifacts are done away with employing colour correction schemes, the optimal seam is generated either in spatial domain or solved as an optimization problem and the colour correction requires transition smoothening across the optimal seam. In the remaining of the paper we will discuss the methods we used for optimal seam selection for stitching and color blending and compare the results of generated panoramic images with those obtained without color blending.

II. Fundamental Methods for developing Panoramic Montage

The three stages for creating the panoramic collage as proposed in literature are detailed in this section.

Exposure leveling is achieved by optimization of a global error function which is defined on the basis of average values obtained from the overlap pixels considering all combinations of the image slices [1]. The authors [2] [3] [4] alter the luminance component of the slice by mapping it either directly with a basis image or its histogram. Uyttendaele [5] obtain 'blocky' results on exposure alteration by modifying every pixel luminosity as a function of its neighborhood pixels. A very computationally extensive task made easier by use of 32 × 32 block giving patchy results. Gamma correction [6] is used to modify the exposure and luminance level which entails a color correspondence process by choosing the gamma value using a trial and error grid, a modification of the global error function optimized by [7]. The image slices with their adjusted exposures are then to be stitched along the optimal seam. The authors [8] [9] suggest to find the optimal seam wherein the differences in the overlap area of the image slices are minimum. However in order to generate the montage the corresponding pixels need to be copied from the individual slices. Xiong et al [10] suggest a dynamic programming model to find the optimal path where the image slices are to be sutured. The overlap area is extracted and the squared distance between the individual pixels in slices is generated as an error surface. The important step in our proposed algorithm is transition smoothening. The basic idea is to eliminate any artifacts caused during the stitching process.

III. Proposed Algorithm for Image Suture

Images as slices of a wide-angled view are captured for stitching and color blending to obtain a panoramic mosaic. The algorithm we used for our panoramic picture generator primarily uses minimum Euclidean distance calculations to find the neighboring matches in multiple image slices which are supposed to be blended together to for the panorama. Prior to the process of blending, the slices are resized to obtain the same number of rows (r) in each image slice. This ensures accurate image alignment in the vertical plane when the stitching process is done.

A. Exposure Levelling

The exposure in colour images is basically a function of its luminance. Preceding the stitching algorithm, the exposure in the different slices are adjusted to provide colour discontinuities. An adaptive exposure levelling scheme is devised to maintain uniform colour luminosity in all the slices to be stitched.

The exposure of the image slices is revealed by converting them from the RGB to the YCbCr space. Here Y represents the brightness/luminance component accompanied by Cb (blue difference) and Cr (red difference) chroma components. The average luminosity in each slice 'k' is evaluated as (2)

$$Y_k = \frac{\sum_{i=1,j=1}^{i=r,j=c_k} Y_{ijk}}{r * c_k} \quad (2)$$

Where r represents the number of rows in each slice and c_k represents the number of columns in slice k. The vectored luminance is then compared to obtain the slice l with the maximum average luminosity. The luminance component of the remaining slices is modified as a ratio directly proportional to the Y values of slice l. The exposure leveller algorithm follows (3) to modify the brightness of the supplementary slices.

$$Y_{ijk} = Y_{ijk} * \frac{Y_l}{Y_k} \quad (3)$$

B. Proposed Optimal Seam Generation Algorithm

The stitching of the slices follows the process of the exposure leveller algorithm. These modified values of the luminance are used to then obtain the optimal seam values for stitching using the proposed.

{
for k slices
k-1 times
{
m= min $(c_{lk,}c_{rk})$
Slide the slice with m columns over thesecond image horizontally from left to right.
to generate the seam for stitching.
fori =1: m
{
$a_{r\times i} = (c_{lk(ri)} - c_{rk(ri)})$^2
mse (i) =sum(sum(a))/(r × i)
end
}
Optimal seam = i | min(mse)
}

Yao et al. match the luminance in the overlapping regions of the adjacent images in log domain via the gamma correction. For proper color blending, the luminance of each image average values is compared and if one is greater than the other, the vectored luminance values Y are modified accordingly.

C. Graded Colour Correction on Stitching Seam

The optimal seam the area where the two slices of a single image are to be stitched is generated using the mean square criteria entirely stretching the seam. A graded colour emendation is performed to commensurate the colour gradient between the two slices on the optimal seam. The weights are pragmatically applied to individual RGB colour components. For each component the pixel which has a closer proximity to the left edge of the overlap gets a higher weightage from the pixel which is farther away from the right edge. The modified pixel values are in inverse ratio of the Euclidean distances from the either edge. The weights for generating the modified pixel intensities RGB individually are graded increasingly for left slice (w_{lk}) and in the reverse right slice for w_{rk} as given in (4) and (5)

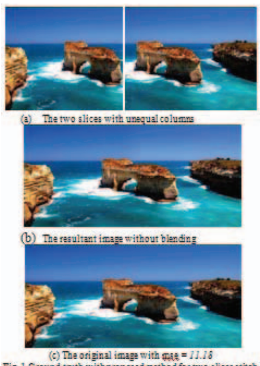
$$w_{lk} = 1/(seam - 1)^2 \quad (4)$$

$$w_{rk} = -1/(seam - 1)^2 \quad (5)$$

where seam is the length of the overlap where the stitching is performed. The aforementioned colour blending scheme is detailed as an algorithm below

for each RGB
{
for i=1: r
{
for j=1:seam
{
$w_{lk}(i,j) = 0{:}\,1/(seam-1)\text{^}2{:}\,1$
$w_{rk}(i,j) = 1{:}\,-1/(seam-1)\text{^}2{:}\,0$
$p_{(ij)new} = \dfrac{(w_{rk}p_{(ij)lk} + w_{lk}p_{(ij)rk})}{seam}$
end
}
end
}
}

Thus, we propose the optimal seam selection algorithm for stitching and color blending to obtain high quality panoramic pictures of accurate and non-patchy luminance as compared to the image stitching results obtained without color blending performed. The basic handicap faced by the authors for such applications is the absence of the ground truth conditions. In order to analyze the veracity of our proposed method we upend our techniques on preexisting panoramic images. The algorithm is executed on three slices of capriciously formulated slices of the panorama. The nominal *mse* values between the resultant image and the ground truth as a consequence of proposed algorithm justifies the use of the later. Fig. 1 shows the two slices of the original image which is our golden standard accompanied by the resultant output generated by our proposed algorithm while Fig. 2 depicts the panorama engendered with three slices. Here we mention that simulation results have been obtained with more than fifteen different combinations of two and three slices and the resultants in each individuality with maximum *mse* is illustrated.



(a) The two slices with unequal columns

(b) The resultant image without blending

(c) The original image with *mse* = *11.18*

Fig 1 Ground truth with proposed method for two slices stitch.

(a) Three slices with unequal columns

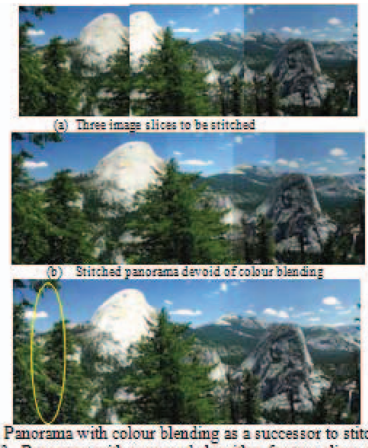
(b) The resultant image without colour blending

mse = 113.18

Fig 2 Ground truth with proposed method for three slices

IV. Simulation Results and Observations

The proposed method is implemented on eight pairs of images with disparity in colour, landscape, cloudscape with both indoor and outdoor vistas differentiated by the number of sutures to be performed.



(a) Three image slices to be stitched

(b) Stitched panorama devoid of colour blending

(c) Panorama with colour blending as a successor to stitching

Fig. 3. Panorama with proposed algorithm for two slices stitch

Fig. 3(b), is experiential that devoid of colour blending, the method shows a very prominent seam at the point of suture. The overlap regions are where the stitch has occurred is clearly visible. The colour blending achieves to remove the artifacts and results in transition smoothening of the area near the optimal seam. Fig.3(c) supports the claim with an highly improved stitch with gradient like increase in the contrast of the image due to colour blending. However the change in the colour contrast (denoted by the yellow circle) is very hardly prominent and provides little or no variation to colour information of the resultant image. This effect is attributed to the fact that the algorithm applies the graded colour correction scheme.

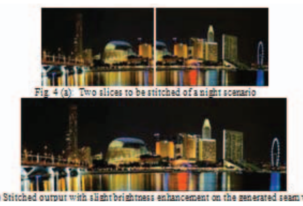


Fig 4 (a) Two slices to be stitched of a night scenario

Fig 4(b) Stitched output with slight brightness enhancement on the generated seam without colour blending

The effect observed in Fig. 5(c) is further abated in case of source images with a dark background. The subjective results are suitably argued using first and second order statistics of mean intensity, Entropy and standard deviation. Table I (a) and (b) detail the generated arithmetical values for the aforementioned parameters for the source images in Fig. 5 with two slice stitch in Fig. 6.

Table I: Statistical Tabulation of source and the resultant sutured images

(a) Three slices (Fig. 3) stitched with and without the process of colour blending

Eval. Parameters	Source Image 1	Source Image 2	Source Image 3	Average	Without colour blending	Deviation from Average	With blending	Deviation from Average
MI	92.335	110.266	84.7493	95.7834	106.2495	+ 9.85	93.3552	- 2.6
Entropy	7.6037	7.7334	7.3648	7.4877	7.7251	+ 3	7.6472	- 2
SD	14.9048	12.8745	6.3810	11.8360	12.0027	+ 1.4	11.9662	+1

No. of overlap columns = 73

% stitch = 17.31

(b) Two slices (Fig. 4) stitched with and without the process of colour blending

Eval. Parameters	Source Image 1	Source Image 2	Average	Without colour Blending	Deviation from Average	With colour blending	Deviation from Average
MI	49.6	44.6191	46.6612	48.7031	+ 4.2	46.4851	(-)
Entropy	6.5864	6.4093	6.4978	6.5759	+1.2	6.5226	- 0.38
SD	19.0792	18.7255	18.902	20.8355	+9.28	20.5634	-8

No. of overlap columns = 347

% stitch = 28.92

The appraisal of the above tables signify the reduction across the parameters in cases of blending performed with added process of graded colour blending as compared to sutures sans the colour correction. These values approximate to the average value of the corresponding parameters obtained from the two/three source with minimal error. The change in deviation specifically in the mean intensity and standard deviation is highly evident (approx 5% to 11% as compared) to the variation in the Entropy. Fig. 5 displays the image sizes for making the panoramic (stitched) images using proposed algorithm to substantiate the aforesaid claims. The information at the seam of the stitch is retained in all the six images.

The variation in stitch with and without colour blending is distinctly observed for image 1 (Fig. 5) and is tabulated in Table II (a). The value addition due to the colour blending is obtained in the cases where the panoramic sources are obtained over different instants of time with vivid light conditions. The images 2-6 are formed using a panorama obtained by sources at infinitesimally small duration of time $(\Delta t \to 0)$ due to which there exists no significant change in the stitch as a consequence of the colour blending. Table II collaborates with what we have envisioned in the panoramic images in Table I. The stitched outputs which are followed by colour blending have their mean intensity closer to the average pixel intensity of the source images as compared with the counter method of solitary stitch. The similar progression is observed in case of Entropy and standard deviation. However numerically the deviation in the aforementioned parameters is considerably less than that in the case of mean pixel intensity.

Conclusion

The proposed method shows gradual merging of the individual montages among the edges where the slices overlap in color, luminance and scene pattern. The optimal seam selection algorithm in cahoots with color blending delivers a patchless seam. The computations required by the system are relatively straight forward and simple as it eliminates gamma correction for exposure leveling, does not require dynamic programming to form the seam or generation of mask for each source slice for colour blending. The beauty of panoramic images in the capturing of wide angled scenic without the curling at the edges or un-patched depiction of the scene being captured is realized by the proposed algorithm.

Fig.5 Collage of images (1-6) with the input slices to the left and the resultant outputs on the right using the proposed method.

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Table II: Statistical Tabulation of source and the resultant sutured images with no ground truth

Evaluation Parameters	Statistical Parameter	Source Image 1	Source Image 2	Source Image 3	Average	Without colour blending	Deviation from Average	With colour blending	Deviation from Average	No. of overlap columns	% stitch
Image 1	**MI**	**132.10**	**118.58**	---	**125.34**	**138.2416**	**12.8994**	**131.4687**	**+6.126**	**776**	**43.12**
	Entropy	**7.399**	**7.0851**	---	**7.2424**	**7.4754**	**0.233**	**7.4598**	**-0.016**		
	SD	**11.14**	**8.29**	---	**9.72**	**10.16**	**0.4346**	**9.3116**	**-0.410**		
Image 2	**MI**	**99.086**	**101.07**	**134.54**	**111.9**	---	---	**135.57**	**+23.67**	**705**	**39.28**
	Entropy	**6.844**	**7.5336**	**7.8496**	**7.409**	---	---	**7.7483**	**+0.339**		
	SD	**11.862**	**13.25**	**10.346**	**11.808**	---	---	**12.851**	**+1.043**		
Image 3	**MI**	**117.33**	**117.07**	---	**117.2**	**116.39**	**-0.7996**	---	---	**173**	**14.42**
	Entropy	**7.5356**	**7.6775**	---	**7.6066**	**7.9957**	**+0.3891**	---	---		
	SD	**9.655**	**9.4123**	---	**9.533**	**12.0675**	**+2.534**	---	---		
Image 4	**MI**	**146.31**	**104.22**	---	**125.28**	**142.14**	**+16.86**	---	---	**223**	**18.58**
	Entropy	**7.7562**	**7.697**	---	**7.7267**	**7.8535**	**+0.1276**	---	---		
	SD	**9.5270**	**8.0587**	---	**8.8063**	**11.568**	**+2.7625**		---		
Image 5	**MI**	**80.82**	**83.66**	**81.892**	**82.12**	---	---	**82.907**	**+0.784**	**250**	**19.3**
	Entropy	**6.0501**	**6.4927**	**6.4485**	**6.3304**	---	---	**6.3342**	**+0.0038**		
	SD	**8.4852**	**8.1486**	**8.4868**	**8.3735**	---	---	**8.567**	**+0.1935**		
Image 6	**MI**	**153.86**	**127.59**	---	**140.72**	**138.24**	**- 2.4817**	---	---	**174**	**14.5**
	Entropy	**7.399**	**7.0851**	---	**7.2424**	**7.4754**	**+ 0.233**	---	---		
	SD	**11.14**	**8.296**	---	**9.722**	**10.157**	**+0.7946**	---	---		