Object Detection using a Novel YIQ Model based Image Fusion for UAV Aerial Surveillance

Thillainayagi.R[#1], Mohamed Rasheed.A*[2], Senthil Kumar.K[#3], Athilingam.R*[4]
[1,2,3,4] Department of Aerospace Engineering, Madras Institute of Technology,
Anna University, Chennai 600044, India
E-mail: thillaimit@gmail.com

Abstract — Multi-sensor image fusion is an important precondition of realizing target perception for unmanned aerial vehicles (UAVs), and then UAV can execute various given missions. Imaging devices on UAV are used to capture visual scenes of the ground and they are fused to extract the information. Both the imaging devices setup in the UAV and the target in the ground are in dynamic environment. Due to the imperfection of imaging device and instability of the observed scene, captured images often blurred and exhibit unsatisfactory spatial resolution. Hence single sensor does not fulfil the visual surveillance need in daytime. This paper propose the concept of fusing multi sensor aerial images captured by UAV using YIQ colour model based on Laplacian pyramid transform with Principal component analysis technique. The performance of the proposed image fusion scheme is analyzed using the evaluation metrics of Entropy, Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) with the existing techniques.

Keyword - Image fusion, PCA, Laplacian Pyramid, YIQ model, UAV, PSNR, RMSE.

I. INTRODUCTION

Unmanned aerial vehicles (UAVs) are aircrafts which have the capability of flight without an onboard pilot. UAV can be remotely controlled, semi-autonomous, autonomous, or have a combination of these capabilities [1]. UAV's widely used for military as well as civil applications. Image processing applications with specific importance to surveillance and reconnaissance is of immense interest. UAVs are equipped with imaging sensor platform, which operates remotely controlled, semi-autonomously or autonomously, without a pilot sitting in the vehicle. The platform may have a small or medium size still-video or video camera, thermal or infrared camera systems, airborne light detection and ranging (LIDAR) system, or a combination thereof. All these different kinds of cameras are an effective sensor tool which is portable, light weight and airborne in a platform on the UAV.

Image fusion is a process of combining two or more images to form a single composite image by utilizing certain features from each image. The successful fusion of images acquired from different sensory system or instruments is of great importance in many applications such as image analysis and computer vision, concealed weapon detection, moving target detection and tracking, border surveillance and autonomous landing guidance. Image fusion can be executed in three levels of the information representation, which are pixel, feature, and symbolic levels. Multi-scale analyses are widely used for analyzing the features of images for image fusion. Several multi-scale analyses are available for image fusion. These include the the Discrete wavelet transform [2], Laplacian and ratio pyramid transform [3], Contrast pyramid transform [4], the gradient pyramid transform [5] and the Principal component analysis [6]. In colour image domain, the application of fusion has been thought as a direct extension of original technique whereby fusion operation applied to one image channel could be directly replicated to the other ones [8]. Colour images fusion algorithms can be divided into two classes: processing in RGB colour model and processing in other transformed colour model such as HSI, Ycbcr, YIQ and so on [8,9]. Processing in RGB model means fusion scheme is implemented in each RGB channel [7], while processing in transformed model usually separates grayscale information from colour data and treats each channel respectively [9].

In this paper, a novel colour aerial image fusion algorithm based on Laplacian Pyramid transform with Principal component analysis method is implemented in YIQ colour model is proposed, aiming at executing the fusion operation quickly and getting better fusion results with more original information and better chromatic interpretation. In the proposed algorithm, Laplacian pyramid is applied to fuse Y components of original images to enhance the sharpness features of luminance component, since in-focus information of original aerial image is mainly contained in luminance component and Principal component analysis method has superior quality in reducing the dimension of image data to increase the speed of image fusion operation in chrominance (I and Q) component. Then the proposed algorithm can provide better chromatic interpretation than algorithms processing in each RGB component which may produce incorrect colours.

II. IMAGE FUSION ALGORITHMS

A. Principal component Analysis

Principal component analysis (PCA) [5] [6] is a vector space transform often used to reduce multidimensional data sets to lower dimensions for analysis. The fused image can be generated by the following steps

Arrange source images (ie. images to be fused) $I_1(i, j)$ and $I_2(i, j)$ in two-column vector.

Step 1. Organize the data into column vector. Let Z is the resulting column vcector of dimension $2\times n$.

Step 2. Compute empirical mean along each column. The empirical mean vector has a dimension 1×2.

Step 3. Subtract empirical mean vector from each column of Z. The resulting matrix X has dimension $2\times n$.

Step 4. Find covariance matrix C of matrix X. Mean expectation will be equal to covariance of X.

Step 5. Compute eigenvectors and eigenvalue and sort them by decreasing order.

Step 6. Consider first column of eigenvector which correspond to larger eigenvalue to compute normalized component P1 and P2. The fused image is

$$I_f(i, j) = P_1 I_1(i, j) + P_2 I_2(i, j) \quad (1)$$

B. Laplacian Pyramid transform

The basic principle of pyramid transform method is to decompose the source image into pieces of sub-images with different spatial resolutions through some mathematical process [13]. An image pyramid comprises of a set of low pass or band pass copies of an image, each copy representing pattern information of a different scale. The Laplacian pyramid is derived from the Gaussian pyramid, which is a multi-scale representation obtained by a recursive low-pass filtering and decimation. The decomposition of Laplacian pyramid transformation has two major phases. 1. Gaussian pyramid decomposition and 2. Gaussian pyramid to Laplacian pyramid. The fused image can be generated using the following steps.

Image decomposition phase has three steps.

Step 1: Input image is convolved with low pass filtering using $W = \left[\frac{1}{16}, \frac{4}{16}, \frac{6}{16}, \frac{4}{16}, \frac{1}{16}\right]$.

Step 2: Subtract the low pass filtered input images and build the pyramid.

Step 3: Decimate the input image matrices by dividing the number of rows and columns by two.

The reconstruction stage has the following steps.

Step 1: Build the image matrix by duplicating every row and column

Step 2 : Matrix addition of the same with the pyramid formed in the corresponding level

C. Proposed YIQ model based image fusion scheme

1) *YIQ Colour model transformation:* The RGB colour model is comprised of the principal colours red component, green component and blue component and is the fundamental and preferable model for displaying colour images. However RGB colour model is not good for fusion of colour aerial images because of the high correlation among the R, G, and B components [11]. Fusion of colour aerial images which is working to R, G and B components respectively may lead to colour distortion and give poor performance in chromatic interpretation**.** To overcome this problem, we can use other colour models such as YIQ which can display different colour characteristics suitable for the fusion application of colour aerial images.

YIQ colour model is also as the same as NTSC colour model. In this colour model, Y represented the luminance component, while I and Q carry the chrominance information [12-13]. The transformation of RGB colour model to YIQ colour model can be derived as,

$$Y = 0.299R + 0.587G + 0.144B \quad (2)$$

$$I = 0.569R - 0.275G - 0.321B \quad (3)$$

$$Q = 0.212R - 0.523G + 0.311B \quad (4)$$

The RGB values can be computed from the components in the YIQ colour model using

$$R = 1.000Y + 0.956I + 0.621Q \quad (5)$$

$$G = 1.000Y - 0.272\,\mathrm{I} - 0.647Q \quad (6)$$

$$B = 1.000Y - 1.106I + 1.703Q \tag{7}$$

2) YIQ model based Image Fusion: The fused image can be generated by the following steps.

Step 1. The input colour aerial images are transformed to YIQ model, for employing different fusion procedures to the corresponding luminance (Y) and chrominance components (I and Q).

Step 2. Laplacian pyramid transform is used to fuse the Y components.

Step 3. I and Q Chrominance components are fused using Principal component analysis technique.

Step 4. After the catenation of Y, I and Q components, the fused images are transformed to the RGB colour model for display by applying Inverse YIQ transform.

The schematic flow diagram of the proposed fusion algorithm of colour aerial images shown in fig 1.

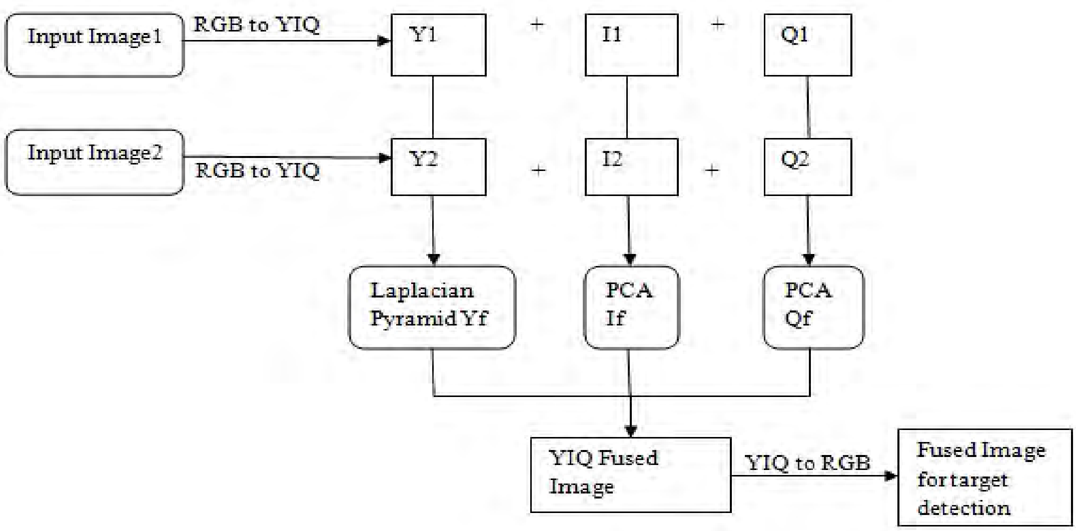

Fig. 1. Schematic Flow diagram of the proposed Algorithm.

In the proposed algorithm, considering Y component contains more information of the source image and is more important than I and Q component in colour aerial images fusion, Laplacian pyramid based fusion algorithm is used to fuse the Y components. In other words, the Y luminance component is selected as the primary fusion variable which is used to compute the focus measure. The more focus details of the Y components are extracted, the better fusion performance is derived. However, in YIQ colour model, there are another two chrominance components: I and Q. Here we simply explain why the two components are not fused using Laplacian pyramid-based fusion algorithm but using PCA-based fusion algorithm because of its reduced dimensionality property. The I and Q components describe the hue and saturation attributes of the colour image.

III. IMAGE FUSION EVALUATION

Image Quality is a characteristic of an image that measures the perceived image degradation. Sometimes the fusion algorithm may introduce some amounts of distortion or artefacts' in the image, so the quality assessment is an important issue. The statistics based image fusion evaluation techniques are Standard deviation, SNR, Entropy, Mean square error and PSNR.

A. Standard deviation

It measures the contrast in the fused image. Fused image with high contrast would have a high standard deviation [10]. For a image with size of $M \times N$, the standard deviation is described in the following equation

$$\sigma_n = \sqrt{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(I(i,j) - \mu_n\right)^2} \tag{8}$$

$$\mu_n = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N} I(i,j) \tag{9}$$

Where ,

σ_n is the standard deviation and μ_n is the mean value of an image.

B. Signal to noise ratio

SNR is defined as the ratio between image mean value and standard deviation described in equation

$$SNR = \frac{\mu_n}{\sigma_n} \tag{10}$$

C. Entropy

Image entropy stands for the average information content in an image and the complexity of an image.

$$H_e = -\sum_{i=0}^{G} P(i)\log_2\left(P(i)\right) \tag{11}$$

$$r = b - H_e \tag{12}$$

Where G is the number of gray level

$P(i)$ is the probability of gray level *i*;

r is the information redundancy;

b is the number of bits of the image.

D. Mean square error

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(I_1(i,j) - I_2(i,j)\right)^2 \tag{13}$$

Where

$I_1(i,j)$ is the perfect image.

$I_2(i,j)$ is the fused image.

i & j are the pixel row and column index.

E. Peak signal to noise ratio

$$PSNR = 10\log_{10}\left(\frac{peak^2}{MSE}\right) \tag{14}$$

IV.RESULTS AND DISCUSSION

Performance of various image fusion algorithms is evaluated and compared by applying the images corresponding to multi-sensor inputs to different image quality subjective metrics. The input images used in all algorithms were pre-registered images, of equal size, taken from corresponding frames of two optical videos. This paper presents various algorithms of image fusion, Principal component analysis, Laplacian Pyramid and YIQ model based Laplacian Pyramid with PCA fusion technique and they are tested for set of optical images and their corresponding fused results are shown in Fig. 2 to Fig.6

Fig. 2. Input Image 1

Fig. 3. Input Image 2

Fig. 4. PCA based Fused Image

Fig. 5. Laplacian Pyramid based fused image

Fig. 6. Proposed YIQ based fused image

TABLE I

S.no	Std deviation	Entropy	SNR	MSE	PSNR
PCA	47.1920	7.4808	9.3069	5.0360	41.1099
Laplacian pyramid	44.3868	7.5367	20.7726	3.6528	42.5045
Proposed technique	44.3906	7.5478	22.8943	2.6986	43.8194

From the above table, it can be clearly seen that higher value of SNR, lower MSE and high PSNR obtained for Proposed YIQ model based fusion scheme indicates that the fused image contains fairly good amount of information present in both the images compared with principal component analysis and Laplacian pyramid method.

V. CONCLUSION

The airborne images obtained from the UAV are analysed in ground control station. Both the imaging systems and targets are in motion, sometimes we can get blurred and noisy images due to instability of imaging system as well as observed scene. In this case, we can improve the performance of target detection of UAV, by employing image fusion methods. Here the fusion of optical images is done and the fused image is given for target detection. The effectiveness of the proposed fusion algorithms are evaluated for fused images, as seen in Fig. 4, Fig.5 and Fig.6. From the Table I, we can conclude that YIQ model based image fusion gives better quality image than other existing methods. Hence YIQ model based Laplacian Pyramid with PCA method of fusion is more suitable for UAV based visual surveillance and reconnaissance compared to existing methods.

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