AN EVALUATION OF COLOR SIFT DESCRIPTORS FOR UNDERWATER IMAGES

Pulung Nurtantio Andono[1], Ricardus Anggi Pramunendar[1], Catur Supriyanto[1], Mochamad Hariadi[2], Kunio Kondo[3]

[1]Faculty of Computer Science, Dian Nuswantoro University, Indonesia
[2]Dept. of Electrical Eng., Sepuluh November Institute of Technology, Indonesia
[3]School of Media Science, Tokyo University of Technology, Tokyo, Japan
Email: pulung@research.dinus.ac.id

ABSTRACT

This paper presents the evaluation of color SIFT in underwater image feature matching. Due to the absorption and scattering of light, underwater image suffer from low contrast and blur. The selection of color spaces is needed to overcome these problems. This paper conducts the evaluation of several color spaces on Scale Invariant Feature Transform (SIFT) descriptor. Using our underwater stereo images dataset collected from Karimunjawa Island Indonesia, we demonstrate that HSV-SIFT performs the best to extract matching point, while RGB-SIFT has better performance to extract many number of keypoints.

Keywords: Underwater images, SIFT, HSV-SIFT, RGB-SIFT, YCbCr-SIFT

1. INTRODUCTION

Image feature matching has been widely used for many application, such as 3D image reconstruction and image retrieval. This process extract the interest features of two or more images and match of these features [1]. SIFT is the most frequently feature matching algorithm used in computer vision field. In underwater image research area, it is not easy to conduct SIFT. Underwater image suffer from low contrast and blur due to the absorption and scattering of light. Moreover, standard SIFT only used grayscale intensities and ignore color changes [2]. Therefore, the selection of color space is important to produce many number of matching point of SIFT.

Several color space for image application has been researched. Asmare *et. al.* [3] evaluated the color space transformation for color image enhancement application. They evaluated eight most common color spaces include RGB, YCbCr, YUV, YDbDr, HSV, HSI, XYZ, CIELAB, CIELUV, and CIELCH. It can be denied that the selection of color space affect the next stage for many image application. Related to SIFT, RGB-SIFT and HSV-SIFT have been evaluated by Dan-ni AI *et. al.* [4] for object and scene classification.

Based on the related paper above, this paper evaluates both conventional color SIFT HSV-SIFT and YCbCr for underwater images. The remaining of the paper is organized as follows. Next section discusses about the SIFT and color SIFT feature matching. Section 3 presents our experiment design. Section 4 discusses the results of our experiment. Section 5 concludes the paper.

2. THEORITICAL BACKGROUND

2.1. Scale Invariant Feature Transform

SIFT was developed by Lowe [5] to extract and match the features between two images in the same object. SIFT widely used in object recognition and object tracking. The SIFT algorithm has four major stages: Scale-space extrema detection, keypoint localization, orientation assignment and keypoint descriptor. A brief description of the SIFT algorithm is provided below.

a. Scale-Space Extrema Detection
   This step identifies all potential key point on all scales. Given the scale of an image space as a function of $L(x, y, \sigma)$, i.e the convolution between the Gaussian Kernel $G(x, y, \sigma)$ with the image $I(x, y)$ [5].
   Operator difference of Gaussian (DOG) is used to find features on the imagery by compiling octave image pyramid with different scales.

$$D(x, y, \sigma) = \big(G(x, y, k\sigma) - G(x, y, \sigma)\big) * I(x, y)$$
$$= L(x, y, k\sigma) - L(x, y, \sigma) \quad (1)$$

b. Keypoint Localization
   In this stage, stable keypoint will be selected from keypoint candidates. The emergence of feature-level stability is based on the features of each octave.
c. Orientation Assignment
   Orientation of the keypoint based on local gradient direction of each image, thus making the descriptor invariant to rotation.

d. Keypoint Descriptor
Local gradient image is computed at each scale region around the keypoint. These are transformed into representation that allows the distortions and illumination changes of shape.

2.2. RGB-SIFT

RGB-SIFT theory refers to Dan-ni *et. al.* [4] which use 384 dimensional descriptors to represent a feature vector. RGB-SIFT descriptor of a keypoint D is shown in Eq. 2.

$$D = [h_{R1}h_{R2} \dots h_{R128}h_{G1}h_{G2} \dots h_{G128}h_{B1}h_{B2} \dots h_{B128}] \quad (2)$$

where D denotes the RGB-SIFT descriptor of a keypoint and $h_{R_n}, h_{G_n}, h_{B_n}$ (n = 1, 2,... 128) denote orientation bins of a key point for each channel, respectively.

2.3. HSV-SIFT

Hue Saturation Value (HSV) color space gives more advantages in many image application since it perfectly separate the luminance component from the chrominance information [3]. The conversion of RGB into HSV is given in the Eq. 6-8.

$$M = \max(R, G, B) \quad (3)$$

$$m = \min(R, G, B) \quad (4)$$

$$C = \mathrm{M} - \mathrm{m} \quad (5)$$

$$H = \begin{cases} 0, \; if max = min \\ \left(60^o \times \frac{G-B}{C} + 360^o\right) mod\ 360^o, if\ max = R \\ 60^o \times \frac{B-R}{C} + 120^o, if\ max = G \\ 60^o \times \frac{R-G}{C} + 240^o, if\ max = B \end{cases} \quad (6)$$

$$S = \begin{cases} 0, if\ max = 0 \\ \frac{max-min}{max} = 1 - \frac{min}{max}, otherwise \end{cases} \quad (7)$$

$$V = M \quad (8)$$

2.4. YCbCr –SIFT

YCbCr is useful for image compression application [3]. The Y in YCbCr denotes the luminance component, and Cb and Cr represent the chrominance factors. YcbCr has been proposed to solve the problem of illumination [6]. The conversion of RGB into YcbCr is given in the Eq. 9.

$$[Y\ Cb\ Cr] = [R\ G\ B] \begin{bmatrix} 0.2999 & -0.168935 & 0.499813 \\ 0.587 & -0.3311665 & -0.418531 \\ 0.114 & 0.50059 & -0.081282 \end{bmatrix} \quad (9)$$

3. EXPERIMENT DESIGN

The result of this paper is comparison of RGB-SIFT, HSV-SIFT and YCbCr-SIFT in underwater images. Our underwater image is converted from RGB to HSV and YCbCr. The coral reef surveyed as a use case for this study is located in Karimunjawa Island Central Java. Karimunjawa is a National Marine Park declared as a Natural Conservation Area by Decree of the Minister of Forestry, located at 5°49’-5°57’ South Latitude and 110°04'-110°40' East Longitude in the Java Sea, north of Java, Indonesia. The high level of biodiversity represents the ecosystem of northern coast of Central Java, Indonesia.

A pair Panasonic FT3 cameras and resolution of 1280 x 720 pixels were used to obtain the scene (Fig. 1). Fifty image-pair from the dataset was selected to perform our experiments. Fig. 2 shows the examples of original underwater images.

Performance of SIFT is measured by using an image matching task on a number of stereo underwater images. Matching point are extracted from each of stereo image in the dataset. We used matching degree to compare the performance of different color SIFT. Matching degree of image pair is shown in Eq. 10.

$$\theta = \frac{KeyMatch_{AB}}{\min(KeyNum_A, KeyNum_B)} \times 100\% \quad (10)$$

$KeyMatch_{AB}$ represents the matching points, $KeyNum_A$ and $KeyNum_B$ represent the keypoint number of image-pair A and B, respectively.

Fig. 1. Stereo Camera Installation

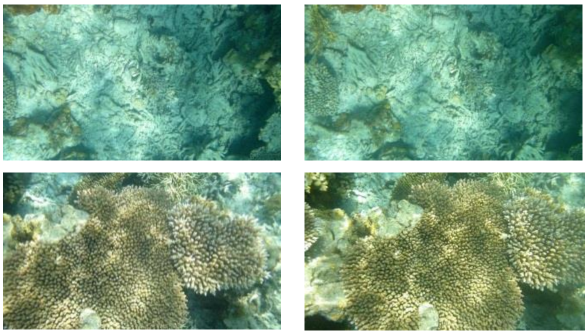

Fig. 2. Original Images-Pair (Left and Right Image)

4. RESULT AND DISCUSSION

Our discussions focus on the performance evaluation and comparison of RGB, HSV and YCbCr color space for SIFT feature matching. In the experiment, we transform RGB images into HSV and YCbCr color space. Original SIFT extracts image features which has 128 dimension (vector). Meanwhile, color SIFT extracts the features keypoints in each channel into a 384 dimension feature vector (128 × 3).

After generating the feature keypoints, the matching keypoints are detected by using the nearest neighbor (Euclidean distance) which has the minimum value. From Fig. 3 and Fig. 4 RGB-SIFT gives many number of keypoints in the most of underwater stereo images. Fig. 5 and Fig. 6 shows the number of matching point and matching degree of SIFT in various color space, respectively. Averagely, the matching degree of HSV-SIFT is better than RGB-SIFT and YCbCr-SIFT. The performance of SIFT is best when applied in the HSV-SIFT. It is possible since the intensity and color information in HSV is perfectly separately [3].

Table 1. Average Matching Degree

Total Images	Matching Degree		
	RGB-SIFT	HSV-SIFT	YCbCr-SIFT
55	4.46%	9.31%	3.89%

5. CONCLUSIONS

In order to improve SIFT, this paper apply color SIFT. We transform RGB image into HSV and YCbCr color space. After color space transformation has been performed, SIFT is used to extract the point matching of stereo underwater images. Based on our experiment, HSV-SIFT is good choice to extract many number of matching point of SIFT. Although, RGB-SIFT produces many number of keypoints.

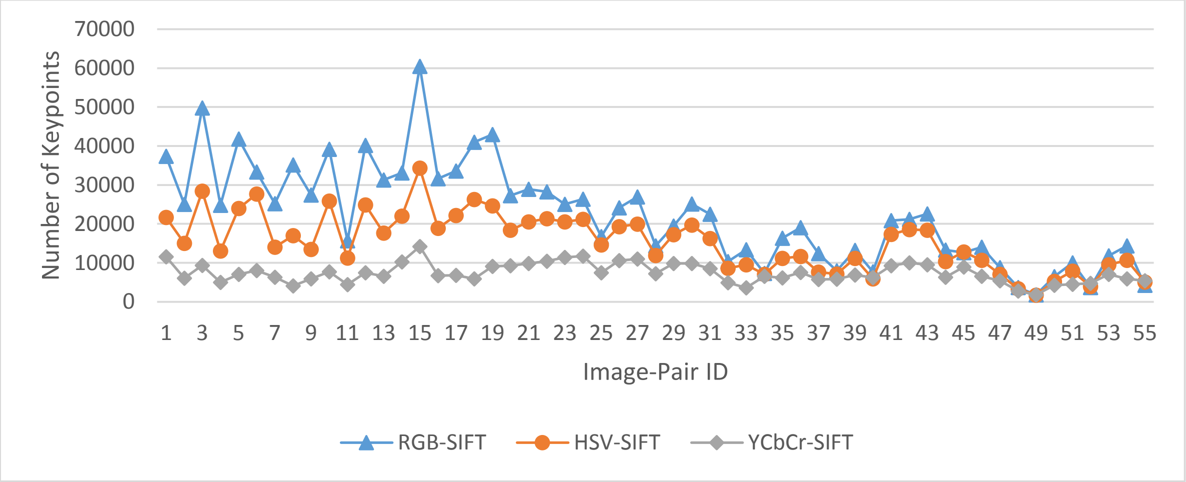

Fig. 3. Number of Keypoints (Right Images)

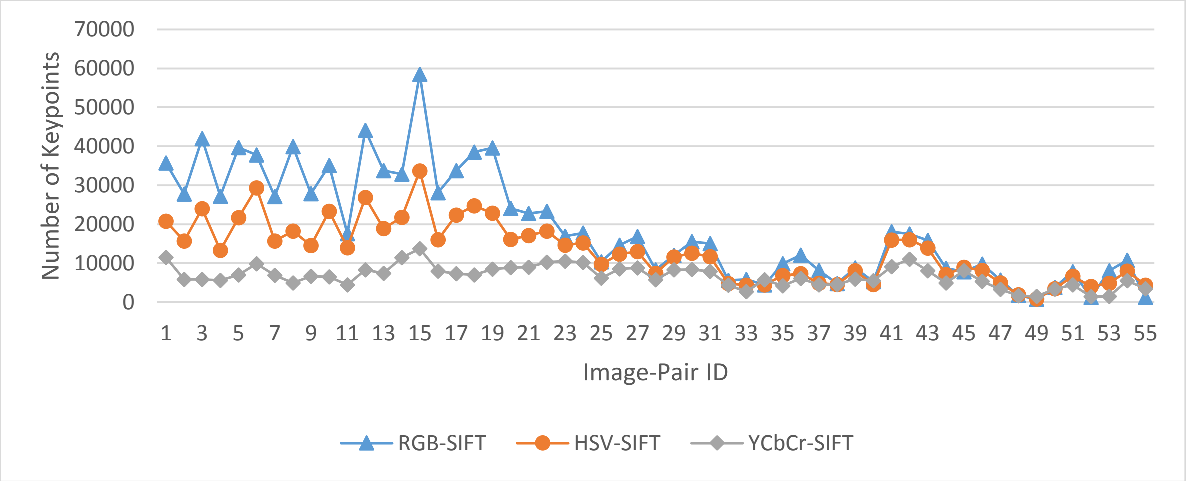

Fig. 4. Number of Keypoints (Left Images)

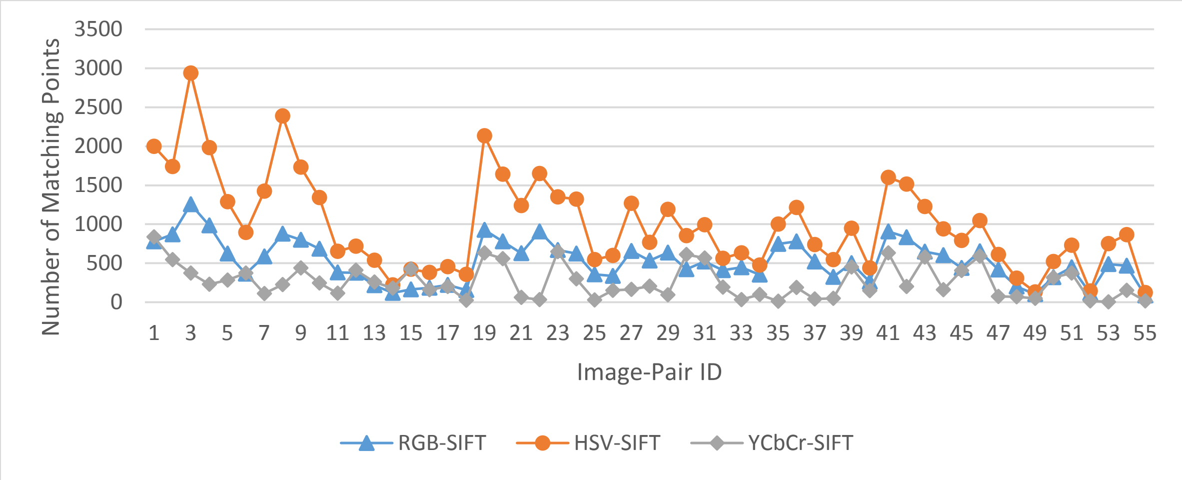

Fig. 5. Number of Matching Point

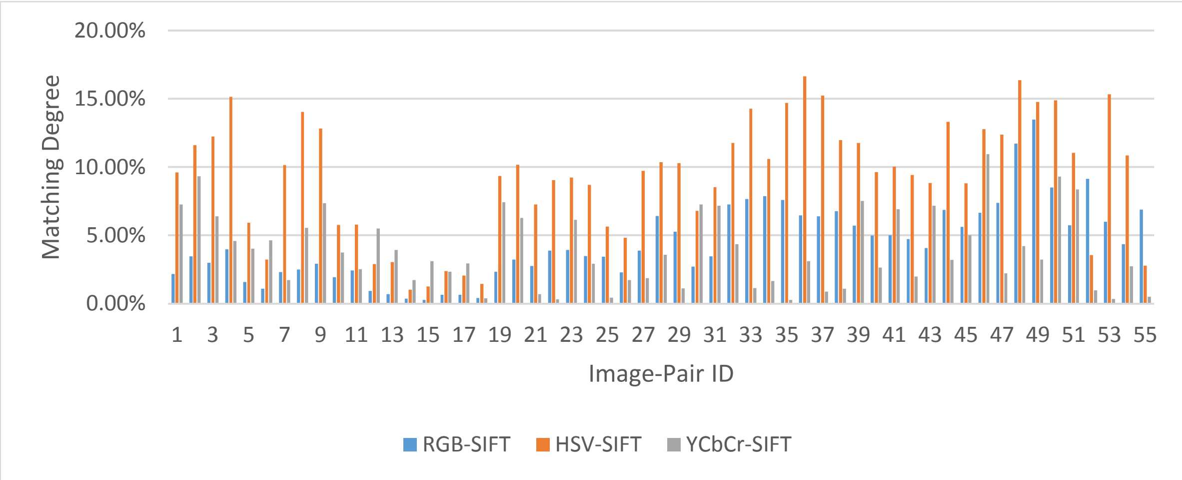

Fig. 6. Matching Degree of Different Color SIFT

REFERENCES

[1] A. Lingua, D. Marenchino and F. Nex, "Performance Analysis of the SIFT Operator for Automatic Feature Extraction and Matching in Photogrammetric Applications," *sensors*, vol. 9, no. 5, 2009.

[2] K. E. A. v. d. Sande, T. Gevers and C. G. M. Snoek, "Evaluation of color descriptors for object and scene recognition," in *IEEE Conf. Computer Vision and Pattern Recognition (CVPR)*, 2008.

[3] M. H. Asmare, V. S. Asirvadam and L. Iznita, "Color Space Selection for Color Image Enhancement Applications," in *International Conference on Signal Acquisition and Processing*, 2009.

[4] D.-n. AI, X.-h. HAN, X. RUAN and Y.-w. CHEN, "Color Independent Components Based SIFT Descriptors for Object/Scene Classification," *IEICE TRANS. INF. & SYST.*, vol. E93–D, no. 9, 2010.

[5] D. Lowe, "Distinctive image features from scale-invariant keypoints," *International Journal of Computer Vision*, vol. 60, pp. 91-110, 2004.

[6] M. H. Saad, H. I. Saleh, H. Konbor and M. Ashour, "Image Retrieval based on Integration between YCbCr Color Histogram and Shape Feature," in *Seventh International Computer Engineering Conference (ICENCO)*, Giza, 2011