COMPARISON OF MATCHING STRATEGIES FOR COLOUR IMAGES

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Abstract: The paper addresses the ubiquitous problem of matching of colour images. Colour plays very important role in human visual system and the question arises how it can influence image matching in case of a computer based vision systems. In this paper the area based matching methods are investigated. Several matching cost functions and different colour spaces (RGB, HSI, YCrCb) are examined. Obtained results for colour are compared with monochromatic methods. Quality of dense disparity maps was verified in two ways: by number of points rejected after cross-checking and by PSNR value between original reference image and its reconstruction from the second reference and disparity map. The main objective of this research is to verify benefits and drawbacks of using colour information for matching versus inevitable costs associated with processing of greater amounts of data.

1 INTRODUCTION

Image matching plays a very important role in vision systems – it is used in computer based stereovision, motion analysis, video indexing, etc. The key problem is finding corresponding points in images. If the corresponding areas are determined the depth of the scene can be computed by triangulation (Cyganek, 2002)(Scharstein, 1998).

Most of the matching techniques use only monochrome (one channel) images (Scharstein, 2002). However, there is still an open question how colour information (more than one channel of data) can help in this task. It is obvious that colour can provide useful information for matching, e.g. red pixel cannot mach witch blue one although their values can be the same. If so, then what colour space and cost measures are the most appropriate and under what conditions.

In this paper we address these questions by providing an overview of the comparison measures appropriate for matching of the colour images and in different colour representations (RGB, HSI, and YCrCb). Matching results were verified by counting number of points rejected after cross-checking as well as by computing the PSNR value between original reference image and its reconstruction obtained from the second reference image and a disparity map.

2 OVERVIEW OF MATCHING TECHNIQUES FOR COLOUR IMAGES

The main idea of area matching is based on estimation of similarity between regions of $n \times m$ pixels from the left and right image, respectively. In case of grey scale images, similarity of two blocks is computed based on some relation between intensity of corresponding pixels. Let us now recall some measures for matching of monochrome and colour images, as follows.

A command is the basic instruction that a script file contains. Some commands require parameters that further define what the command should do. An expression is a combination of operators and arguments that create a result. Expressions can be used as values in any command. Examples of expressions include arithmetic, relational comparisons, and string concatenations.

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M_SAD $$\sum_{(i,j)\in U}\left|I_1(x+i,y+j)-I_2(x+d_x+i,y+d_y+j)\right| \quad (1)$$

M_SSD $$\sum_{(i,j)\in U}\left(I_1(x+i,y+j)-I_2(x+d_x+i,y+d_y+j)\right)^2 \quad (2)$$

M_ZSAD $$\sum_{(i,j)\in U}\left|\left(I_1(x+i,y+j)-\overline{I_1(x,y)}\right)-\left(I_2(x+d_x+i,y+d_y+j)-\overline{I_2(x+d_x,y+d_y)}\right)\right| \quad (3)$$

M_ZSSD $$\sum_{(i,j)\in U}\left[\left(I_1(x+i,y+j)-\overline{I_1(x,y)}\right)-\left(I_2(x+d_x+i,y+d_y+j)-\overline{I_2(x+d_x,y+d_y)}\right)\right]^2 \quad (4)$$

M_GRAD $$\sum_{(i,j)\in U}\left(\frac{1}{2}\left(\left|\nabla I_1(x+i,y+j)\right|+\left|\nabla I_2(x+d_x+i,y+d_y+j)\right|\right)-c\left|\nabla I_1(x+i,y+j)-\nabla I_2(x+d_x+i,y+d_y+j)\right|\right) \quad (5)$$

where I_1, I_2 stand for intensities in the left and right image, d_x, d_y are disparities between matching regions U in the left and right image, is the average value of intensity in a region U. Measure (5) was introduced by (Scharstein, 1998).

Comparison of colour images requires calculations in the multi-channel signal space. To simplify notation of the formulas let us define the following abbreviations:

$$R_1 = R_1(x+i,y+j) \qquad R_2 = R_2(x+i+d_x,y+j+d_y) \quad (6)$$

$$G_1 = G_1(x+i,y+j) \qquad G_2 = G_2(x+i+d_x,y+j+d_y) \quad (7)$$

$$B_1 = B_1(x+i,y+j) \qquad B_2 = B_2(x+i+d_x,y+j+d_y) \quad (8)$$

Based on (1)-(4) and with notation (6)-(8) we define the first group (prefix RGB_1_) of measures for the RGB colour space, as follows:

RGB_1_SAD $$\sum_{(i,j)\in U}\left|\sqrt{R_1^2+G_1^2+B_1^2}-\sqrt{R_2^2+G_2^2+B_2^2}\right| \quad (9)$$

RGB_1_SSD $$\sum_{(i,j)\in U}\left(\sqrt{R_1^2+G_1^2+B_1^2}-\sqrt{R_2^2+G_2^2+B_2^2}\right)^2 \quad (10)$$

RGB_1_ZSAD $$\sum_{(i,j)\in U}\left|\sqrt{(R_1-\overline{R_1})^2+(G_1-\overline{G_1})^2+(B_1-\overline{B_1})^2}-\sqrt{(R_2-\overline{R_2})^2+(G_2-\overline{G_2})^2+(B_2-\overline{B_2})^2}\right| \quad (11)$$

RGB_1_ZSSD $$\sum_{(i,j)\in U}\left(\sqrt{(R_1-\overline{R_1})^2+(G_1-\overline{G_1})^2+(B_1-\overline{B_1})^2}-\sqrt{(R_2-\overline{R_2})^2+(G_2-\overline{G_2})^2+(B_2-\overline{B_2})^2}\right)^2 \quad (12)$$

The second group (RGB_2_) of measures for the RGB colour space is as follows:

RGB_2_SAD $$\sum_{(i,j)\in U}\left(|R_1-R_2|+|G_1-G_2|+|B_1-B_2|\right) \quad (13)$$

RGB_2_SSD $$\sum_{(i,j)\in U}\left((R_1-R_2)^2+(G_1-G_2)^2+(B_1-B_2)^2\right) \quad (14)$$

RGB_2_ZSAD $$\sum_{(i,j)\in U}\left(\left|(R_1-\overline{R_1})-(R_2-\overline{R_2})\right|+\left|(G_1-\overline{G_1})-(G_2-\overline{G_2})\right|+\left|(B_1-\overline{B_1})-(B_2-\overline{B_2})\right|\right) \quad (15)$$

RGB_2_ZSSD $$\sum_{(i,j)\in U}\left(\left((R_1-\overline{R_1})-(R_2-\overline{R_2})\right)^2+\left((G_1-\overline{G_1})-(G_2-\overline{G_2})\right)^2+\left((B_1-\overline{B_1})-(B_2-\overline{B_2})\right)^2\right) \quad (16)$$

For the HSI space and with the abbreviations analogous to (6)-(8), the first group (prefix HSI_1_) of measures is defined as follows:

	FOR ACHROMATIC REGIONS:	FOR CHROMATIC REGIONS:	
HSI_1_SAD	$\sum_{(i,j)\in U}\|I_1-I_2\|$	$\sum_{(i,j)\in U}\left(\|I_1-I_2\|+\|H_1-H_2\|\right)$	(17)
HSI_1_SSD	$\sum_{(i,j)\in U}(I_1-I_2)^2$	$\sum_{(i,j)\in U}\left((I_1-I_2)^2+(H_1-H_2)^2\right)$	(18)
HSI_1_ZSAD	$\sum_{(i,j)\in U}\left\|(I_1-\overline{I_1})-(I_2-\overline{I_2})\right\|$	$\sum_{(i,j)\in U}\left(\left\|(I_1-\overline{I_1})-(I_2-\overline{I_2})\right\|+\|H_1-H_2\|\right)$	(19)
HSI_1_ZSSD	$\sum_{(i,j)\in U}\left((I_1-\overline{I_1})-(I_2-\overline{I_2})\right)^2$	$\sum_{(i,j)\in U}\left(\left((I_1-\overline{I_1})-(I_2-\overline{I_2})\right)^2+(H_1-H_2)^2\right)$	(20)

where the achromatic regions are these where more than 60% of pixels meet the following conditions (Koshan, 1996)(Tseng, 1992): (I>0.95 ∨ I≤0.25) or (0.8<I≤0.95 ∧ S<0.18), or,(0.6<I≤0.8 ∧ S<0.2), or (0.5<I≤0.6 ∧ S<0.3), or,(0.4<I≤0.5 ∧ S<0.4), or (0.25<I≤0.4 ∧ S<0.6), or, The second group (HSI_2_) of measures, operating on the separate channels of the HSI colour space, are defined as follows:

$$\text{HSI\_2\_SAD} \quad \sum_{(i,j)\in U} \left(|I_1 - I_2| + \left|\frac{S_1 - S_2}{\alpha}\right| + \left|\frac{H_1 - H_2}{\beta}\right| \right) \tag{21}$$

$$\text{HSI\_2\_SSD} \quad \sum_{(i,j)\in U} \left((I_1 - I_2)^2 + \left(\frac{S_1 - S_2}{\alpha}\right)^2 + \left(\frac{H_1 - H_2}{\beta}\right)^2 \right) \tag{22}$$

$$\text{HSI\_2\_ZSAD} \quad \sum_{(i,j)\in U} \left(\left|(I_1 - \overline{I_1}) - (I_2 - \overline{I_2})\right| + \left|\frac{(S_1 - \overline{S_1}) - (S_2 - \overline{S_2})}{\alpha}\right| + \left|\frac{H_1 - H_2}{\beta}\right| \right) \tag{23}$$

$$\text{HSI\_2\_ZSSD} \quad \sum_{(i,j)\in U} \left(((I_1 - \overline{I_1}) - (I_2 - \overline{I_2}))^2 + \left(\frac{(S_1 - \overline{S_1}) - (S_2 - \overline{S_2})}{\alpha}\right)^2 + \left(\frac{H_1 - H_2}{\beta}\right)^2 \right) \tag{24}$$

where α and β are scaling coefficients (for 8 bits per channel, $\alpha=\beta=16$ what means that only 5 oldest bits are taken into consideration).

For the YCrCb space the two measures are introduced based on the following scheme:

$$\text{YCrCb\_}k\text{\_SAD} \quad \sum_{(i,j)\in U} \left(|Y_1 - Y_2| + w_r |Cr_1 - Cr_2| + w_b |Cb_1 - Cb_2| \right) \tag{25}$$

The YCrCb_1_SAD is derived from (13) with w_i defined as follows:

$$w_i = \begin{cases} 1 & if \quad Ci > \tau \\ 0 & otherwise \end{cases} \tag{26}$$

where τ is a threshold value.

The second measure YCrCb_2_SAD is derived from (25) with w_i defined as follows:

$$w_i = 1/\alpha \tag{27}$$

where α is a scaling coefficients (for 8 bits per channel, $\alpha=8$ means that only 5 oldest bits are taken into consideration).

Formula (5) for the M_GRAD measure has been extended to cope with different colour spaces:

$$\text{\_GRAD} \quad \sum_{(i,j)\in U} \left[\alpha \left(\sum_{k=1}^{3} |\nabla C_1(k)| + \sum_{k=1}^{3} |\nabla C_2(k)| \right) - \beta \left(\sum_{k=1}^{3} |\nabla C_1(k) - \nabla C_2(k)| \right) \right] \tag{28}$$

where $C_1(k)$ and $C_2(k)$ stand for the *k-th* colour channel (e.g. R, G, and B) for the first and second image, respectively, with the assumptions introduced by formulas (6)-(8); α and β are scaling coefficients (in experiments: $\alpha=0.5$ and $\beta=1$). From (28) we obtain the specific measures for each of the colour spaces: RGB_GRAD, HSI_GRAD, and YCrCb_GRAD.

Finally we incorporate the two additional measures which define yet another kind of distances between colour vectors C_1 and C_2. For the RGB colour space it takes the following form (Loo, 2002):

$$\text{RGB\_DST} \quad \sum_{(i,j)\in U} dist\ (C_1, C_2) \tag{29}$$

where:

$$dist\,(C_1, C_2) = r' + g' + b' + \sigma$$

$$r' = |R_1 - R_2|,\ g' = |G_1 - G_2|,\ b' = |B_1 - B_2|$$

$$\sigma = (|r' - g'| + |r' - b'| + |g' - b'|)/3$$

For matching in the HSI space Wei et.al. (Wei, 2003) propose a modified measure that is based on the well known Minkowski's formula. This modification is given as follows:

$$\text{HSI\_DST} \quad \sum_{(i,j)\in U} \sqrt{|H_1 - H_2|^3 + |S_1 - S_2|^2 + |I_1 - I_2|} \tag{30}$$

HSI_DST reflects meaning of each of the components from the HSI space as perceived by humans. We incorporated this measure to our experiments as well.

Displacements in (29) and (30) between colour vector with indices 1 and 2, with respect to the *(i,j)* indices, follow the assumptions introduced in (6)-(8). 3 Experimental Results

Figure 1 depicts disparity maps for Relaxing Jack test pair. Size of the matching window is 8x8 pixels.

The acquired maps are presented for monochromatic and some colour correlation measures. Number of mismatched points defined by mutual validation of disparity maps, is lowered by 20%-30%. Quality improvement of the results is measured also by a difference between the original image and the image reconstructed from the disparity map; PSNR ratio is improved approximately by 1dB. In this case colour information results in significant improvement in image matching.

Figure 2 and Figure 3 depict depth maps for Cones and Tsukuba stereo pairs. In both cases there are not evident benefits of using colour data. Comparing results for monochrome and colour signals there is no significant improvement for the latter. The number of mismatched points in cases of the best cost functions varies approximately by 5%. In case of the HSI colour space the number of mismatched points increases up to 50%. Results acquired by the mutual validation of depth maps are affirmed by the measurement of the PSNR ratio between the original and reconstructed images.

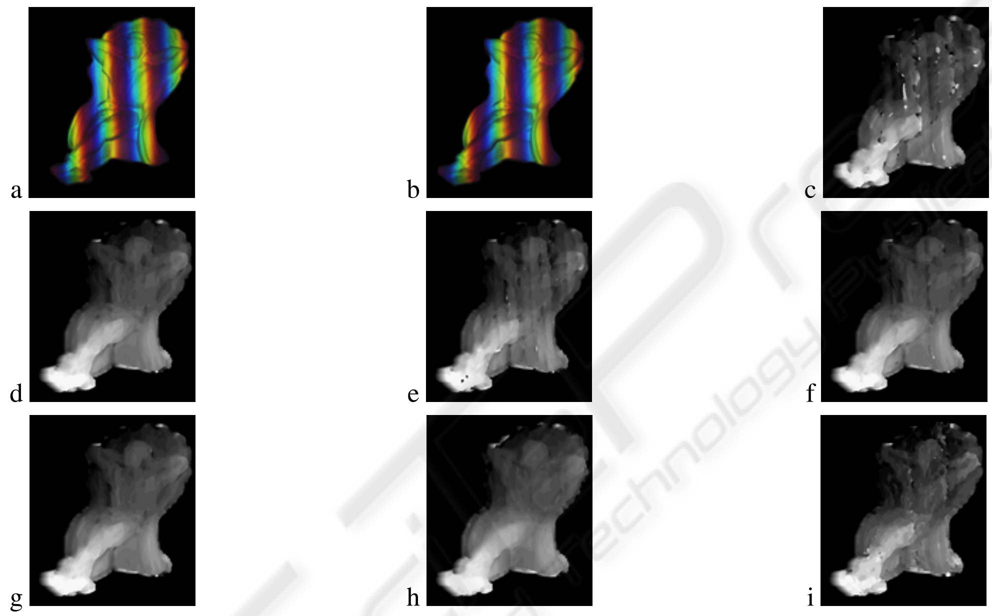


Figure 1: Disparity maps for the Relaxing Jack, block size 8x8. (a) left image, (b) right image, (c) disparity map for M_SAD, false matches: 16,49%, (d) disparity map, RGB_2_SAD, false matches: 13,2%, (e) disparity map, HSI_2_SAD, false matches: 15,25%, (f) disp. map, YCrCb_2_SAD, false matches: false matches: 14,99%, (g) disp. map, RGB_GRAD, false matches: 20,18%, (h) disp. map, RGB_DST, false matches: 13,23%, (i) disp. map, HSI_DST, false matches: 11,93%.

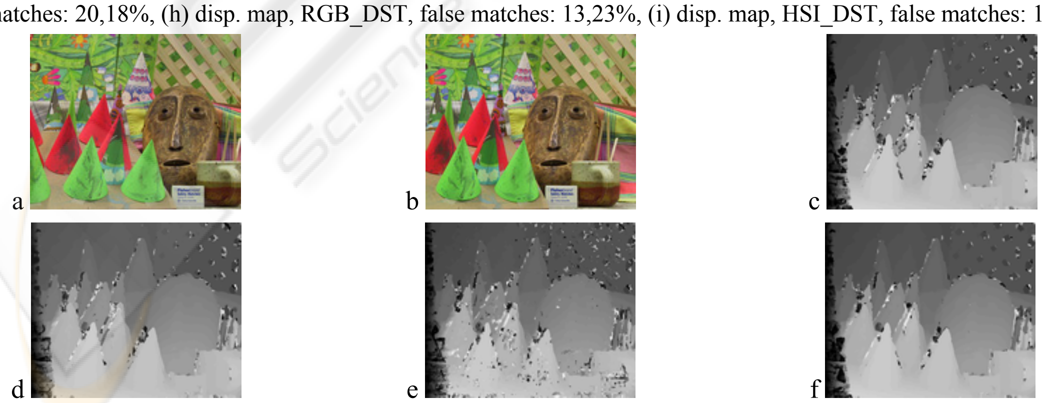


Figure 2: Disparity maps for Cone, block size 8x8 (a) left image, (b)right image, (c) disparity map, M_ZSAD, false matches: 14,93%, (d) disparity map, RGB_2_ZSAD, false matches: 14,8%, (e) disparity map, HSI_2_ZSAD, false matches: 22,86%, (f) disparity map, YCrCb_2_ZSAD, false matches: 14,53%.

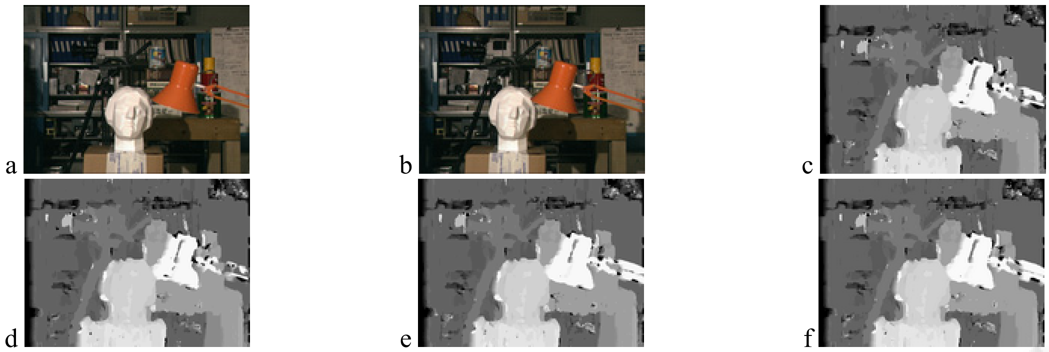


Figure 3: Disparity maps for Tsukuba, block size 8x8 (a) left image, (b)right image, (c) disparity map, M_SAD, false matches: 19,62%, (d) disparity map, RGB_1_SAD, false matches: 19,09%, (e) disparity map, YCrCb_1_SAD, false matches: 19,3%, (f) disparity map, RGB_DST, false matches: 18,92%.

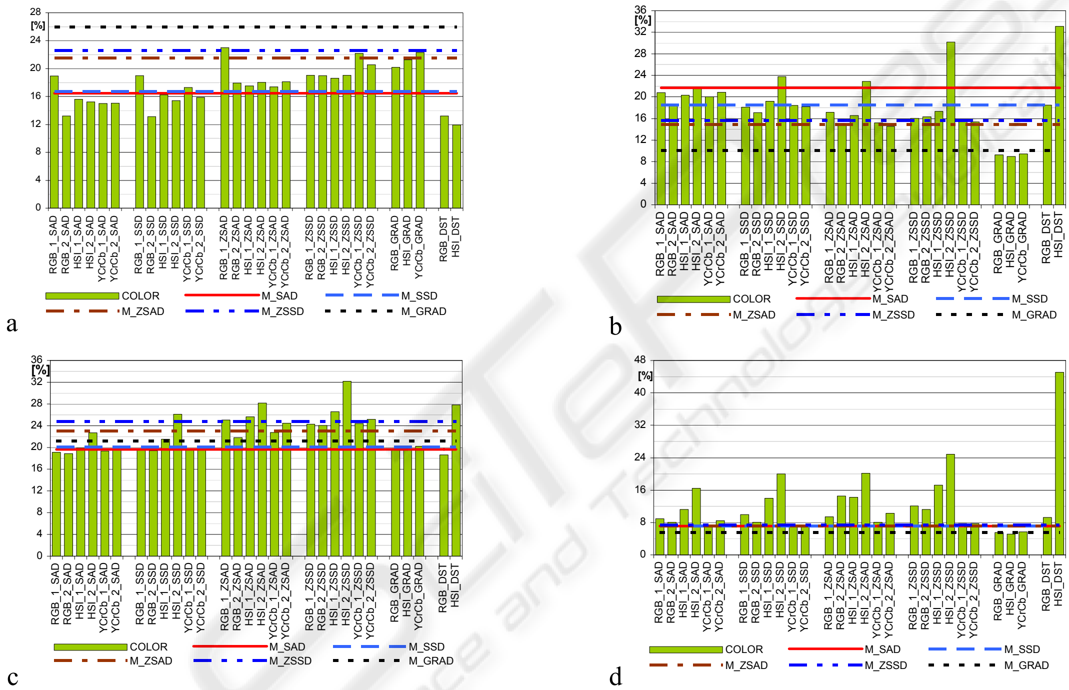


Figure 4: Comparison of matching quality between colour (vert. bars) vs. monochrome matching (horz. lines) – as a function of number of points rejected after cross-checking: (a) Relaxing Jack, (b) Cone, (c) Tsukuba, (d) Sawtooth.

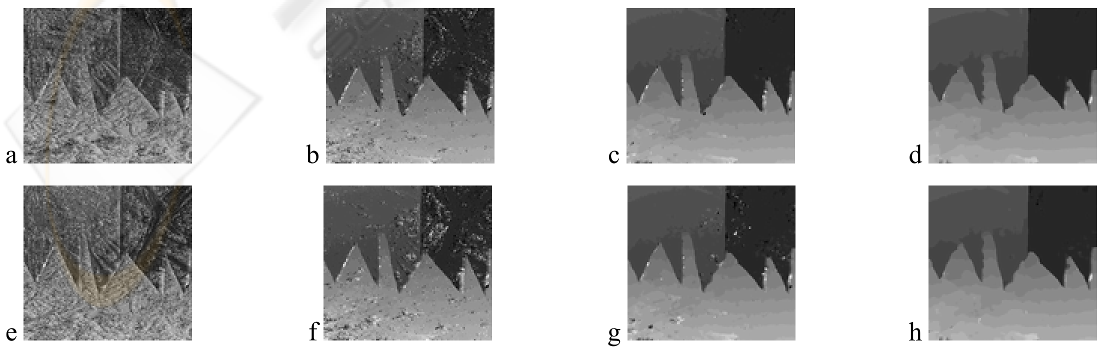
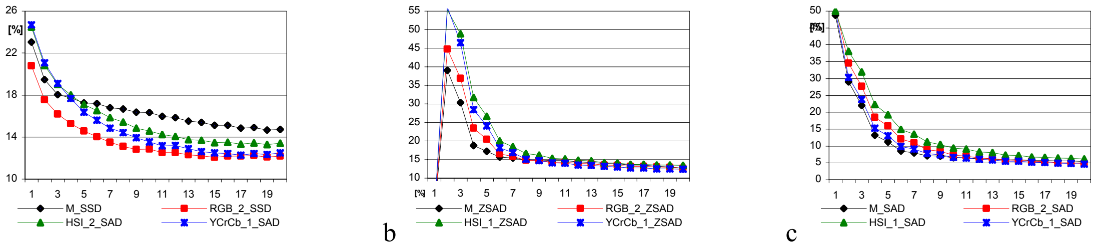


Figure 5: Disparity maps for Sawtooth (a) M_SAD, block size 1x1, false matches: 48,78%, (b) M_SAD, size 3x3, false matches: 21,99%,(c) M_SAD, size 7x7, false matches: 7,99%, (d) M_SAD, size 13x13, false matches: 6,16%, (e) RGB_2_SSD, size 1x1, false matches: 51,01%, (f) RGB_2_SSD, size 3x3, false matches: 27,75%, (g) RGB_2_SSD, size 7x7, false matches: 10,9%, (h) RGB_2_SSD, size 13x13, false matches: 6,28%.



a b c

Figure 6: False matches after validation as a function of block size for different methods: (a) Relaxing Jack, (b) Cones, (c) and Sawtooth stereo pairs.

Figure 4 presents bar graphs comparing matching quality between colour (vertical bars) versus monochrome matching (horizontal lines), in terms of the number of rejected points after cross-checking, for different methods and images. Analyzing this collection, it is clear that results acquired by corresponding methods are similar, except for HSI colour space, where results are significantly worse.

Figure 5 presents depth maps for the Sawtoots pair acquired by matching regions of different size. The two matching measures were used: M_SSD and RGB_2_SSD. Independent of a size of matching regions, the former gave better matching results. However, the latter case is just opposite.

Figure 6 presents plots of false-matches rate, after the validation with cross-checking, as a function of matching block size, for different methods and stereo pairs.

From the presented sets of data we see that for different images there is no significant advantage of colour matching in comparison to the monochrome version. Needless to say, that the latter computations are much more time efficient.

4 CONCLUSIONS

The paper analyses several methods of matching of the colour versus monochrome images. Additional employment of colour information in the area-based matching methods does not give satisfactory results. Although there is thrice more information in colour images, improvement of matching quality (false matches and PSNR after reconstruction from the depth map) is slight or paradoxically it is even aggravated.

In general case incorrect matching of points in monochromatic images is not a result of lack of information in places where matching is possible. Incorrect matching occurs mainly in areas of images with insufficient texture for match discrimination or in occluding places. Unfortunately, addition of colour information does not help in these situations, what was verified by the presented experiments. To the detriment of these simple matching methods the computational complexity is greatly increased.

Apparently the inherent correlation among colour channels cannot result in significant improvements of quality of the resulting disparities. Thus, if higher quality is expected then more advanced methods are recommended than presented in this paper. Alternatively, an acceptable in many applications compromise can be achieved with the simple matching methods presented in this paper and monochrome images.

REFERENCES

Cyganek, B., 2002. *Three Dimensional Image Processing*, (in Polish) EXIT Warsaw, Poland.

Koshan, A., 1997. Improving Robot Vision by Colour Information, *Proc. 7th Int. Conf. on Artificial Intelligence*, Slovakia.

Koshan, A., 1996. Using perceptual attributes to obtain dense depth maps, *Proc. of the IEEE Southwest Symposium on Image Analysis and Interpretation*, USA, pp. 155-159.

Koshan A., Rodehorst V., Spiller K., 1996. Colour Stereo Vision Using Hierarchical Block Matching and Active Colour Illumination, *ICPR `96*, Austria, Vol. I, pp. 835-839.

Scharstein, D., 1998. *View Synthesis Using Stereo Vision*, Lecture Notes on Computer Science No. 1583, Springer, Berlin.

Scharstein, D., Szeliski, R., 2002. A Taxonomy and Evaluation of Dense Two-Frame Stereo Correspondence Algorithms. *International Journal of Computer Vision*, Vol. 47, No. 1-3, pp. 7-42.

Tseng, D., Chang, C., 1992. Colour segmentation using perceptual attributes, *Proc. 11th Int. Conference on Pattern Recognition*, the Netherlands, pp. 228-231.

Wei, B., Liu, Y., Pan, Y., 2003. Using Hybrid Knowledge Engineering and Image Processing in Colour Virtual Restoration of Ancient Murals, *IEEE Trans. on Knowledge and Data Eng.*, Vol. 15, No. 5, pp. 1338-1343.

Loo P.K., Tan C.L., 2002. Adaptive Region Growing Colour Segmentation for Text using Irregular Pyramid, *Technical Report*.