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Performance of Mobile Camera on Colour 2D Barcode

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***Abstract*—In recent years, colour 2D barcodes have emerged to increase the data capacity of the 2D barcode. Similarly, camera-equipped mobile phones have became more popular and their camera could act as an input device for a barcode decoder. In this paper, three Windows Mobile (WM) operated mobile phones are used to test their camera performance in reading the colour 2D barcodes. From the results, recommendations are put forward to those who are developing colour 2D barcode reader for mobile phones.**

I. Introduction

In recent years, the two dimensional (2D) barcodes have been developed to enhance the data capacity of the traditional one dimensional (1D) barcode [1]. The increase of data capacity enables the 2D barcodes to improve their robustness to errors. While the 1D barcodes have redundancy in the vertical direction, this does not exist in the 2D barcodes. Therefore, the error correction ability is important for the 2D barcodes since they can be damaged due to being torn, smudged, crumbled and so forth. In order to increase data capacity, some 2D barcodes use colour to create more symbols, resulting in larger data capacity within the same barcode symbol size.

Similarly, over the last few years, camera-equipped mobile phones have became more popular and the camera has since been the most significant hardware improvement [2]. The camera function enables the phone to interact with physical objects such as a barcode by acting as an input device.

The effect of lighting on colour 2D barcode is often not uniform and accurate representation of the colour is usually challenging. As depicted in Fig. 1 [3], the colour has a different hue of red value under different intensity of lighting.

In this paper, three mobile phones are selected to evaluate their peformance on samples of colour 2D barcodes and the results are discussed. Based on the results finding, various considerations and recommendations are put forward to developers in colour 2D barcode reader for mobile phone.

This paper is organised as follows. A brief introduction is provided in this section. In Section II, the use of colour barcode and selection of mobile phones are discussed. This is followed by the testings and the results in Section III while the conclusion can be found in Section IV.

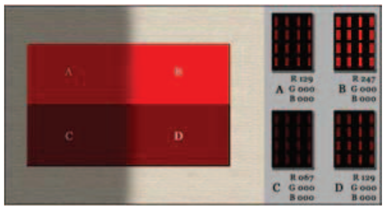

Fig. 1. Effect of Lighting on Colour Value

II. Colour Barcode and Mobile Phones Used

A. Colour Barcodes

In this paper, 20 samples of a 15×15 colour 2D barcode are being used for the testing of the mobile camera. In each sample, there are 10 different colours used to create 10 different type of symbols for the barcode as shown in Table I.

TABLE I
Ten Symbols and Their RGB Colour Space Representation

Symbol Number	Red	Green	Blue
1	0.0	0.0	0.0
2	0.5	0.0	0.0
3	1.0	0.0	0.0
4	0.0	0.5	0.5
5	0.5	0.5	0.5
6	1.0	0.5	0.5
7	0.0	1.0	1.0
8	0.5	1.0	1.0
9	1.0	1.0	1.0
10	1.0	1.0	0.0

One of the barcode created using these 10 symbols is illustrated in Fig. 2. The physical dimension of the barcodes is 5 cm by 5 cm and it is printed on paper for this testing purpose.

B. Mobile Phones Used

In this paper, three WM mobile phones are used for testing. They are:

- i-mate JASJAM,
- Palm Tero 750, and
- HTC Touch Diamond.

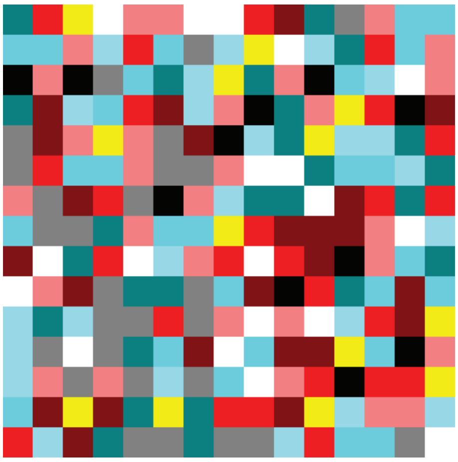

Fig. 2. One of the Colour 2D Barcode

Fig. 3. Captured by JASJAM

Fig. 4. Captured by Tero 750

Fig. 5. Captured by Touch Diamond

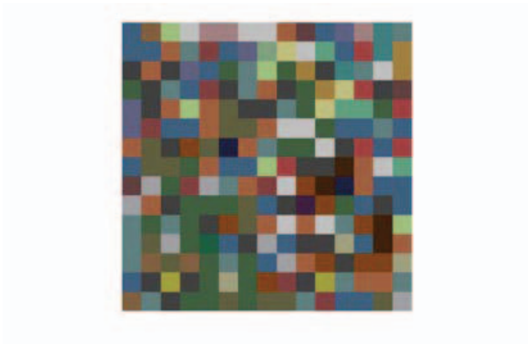

Fig. 6. Pre-processed Barcode Image Before Classification

The three phones are generally different from each other. Their specifications and the year that they are launched are given in Table II.

TABLE II
THE SPECIFICATIONS OF THE MOBILE PHONES

	JASJAM[a]	Tero 750[b]	Touch Diamond[c]
Operating System	WM 5	WM 6	WM 6.1
Camera Resolution	2 Megapixel	1.3 Megapixel	3.2 megapixel
Year Launched	2006	2007	2008

[a] i-mate JASJAM
[b] Palm, Tero 750
[c] HTC Touch Diamond

III. Experimental Results

All testings are conducted in an office lighting environment. In order to remain consistency throughout, the printed barcodes are captured with image size of 1 Megapixel. The images are all saved in Joint Photographic Experts Group (JPEG) format. The remaining setting for the cameras are put to "AUTO" mode. The captured images of Fig. 2 are presented in Fig. 3, 4 and 5.

After the images are captured, the centre of each cells are read. Their respective RGB values are recorded for analysis purpose. For example, one of the pre-processing barcode from the cells is depicted in Fig. 6.

The performance of the cameras is evaluated using three performance indicators. They are:

- Movement of Colour Test,
- Grouping Test, and
- Minimum Euclidean Distance betweens Symbols Test.

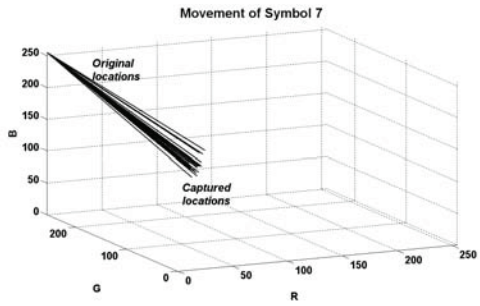

Fig. 7. Captured Locations of Symbol 7

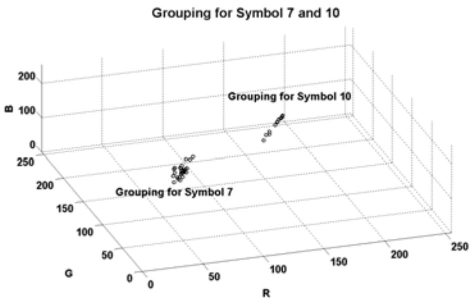

Fig. 8. Grouping for Symbol 7 and 10

A. *Movement of Colour Test*

As the images are captured from a printed media, the captured intensity of each colour component tend to shift away from its original values. Comparing the original barcode (Fig. 2) with the captured ones (Fig. 3, 4 and 5), the captured ones appear darker. For example, the captured locations of the Symbol 7 has shifted as depicted in Fig. 7.

For quantitative comparison, the Euclidean distance (D) between the original location (R_1 G_1 B_1) and their respective captured location (R_2 G_2 B_2) in the RGB colour space representation of each cell is determined by

$$D = \sqrt{(R_2 - R_1)^2 + (G_2 - G_1)^2 + (B_2 - B_1)^2}. \qquad (1)$$

Hence, for better performance, this Euclidean distance shall be minimum. The performance results of the three phones for this test are provided in Table III.

TABLE III
PERFORMANCE IN MCT

Symbol	JASJAM	Tero 750	Touch Diamond
1	71.36	36.84	101.54
2	84.80	64.27	101.01
3	132.58	100.20	164.16
4	80.92	80.52	88.07
5	77.07	107.56	68.46
6	121.12	112.40	101.27
7	219.16	230.99	230.59
8	173.82	207.44	190.63
9	134.87	182.00	154.57
10	153.78	145.75	163.43
Average	124.95	126.80	136.37

As shown in Table III, Symbol 7 moves the most across the three phones. The performance of the three phones in the Movement Colour Test are generally the same for i-mate JASJAM and Palm Tero 750 whereas the HTC Touch Diamond is slightly worse off.

B. *Grouping Test*

Another important test conducted for this paper is grouping of the similar symbols. As portrayed in Fig. 8, the captured symbols will not fall on the similar location. It is important for the similar symbols to be close to each other so as to achieve better decoding results. If they are far apart, it might be possible for one to be wrongly decoded as another symbol.

Within the same barcode, all the captured symbols are grouped together based on its original location. Within the same group, a reference point ($R_{\text{ref}}, G_{\text{ref}}, B_{\text{ref}}$) is calculated based on the mean of all the symbols' RGB values (R_i, G_i, B_i) as

$$\{R_{\text{ref}}, G_{\text{ref}}, B_{\text{ref}}\} = \left\{ \frac{\sum_{i=1}^{N} R_i}{N}, \frac{\sum_{i=1}^{N} G_i}{N}, \frac{\sum_{i=1}^{N} B_i}{N} \right\}, \qquad (2)$$

where N is the total number of similar symbol within the group.

Thereafter, the Euclidean distance between each captured symbol and its reference points is calculated using (1). Within the same group, the quantitive grouping value for each symbol is obtained based on

$$\sigma^2 = \frac{1}{N-1} \sum_{i=1}^{N} (x_i - \bar{x})^2, \qquad (3)$$

where x_i is the Euclidean distance of each captured symbol and the its reference points, and $\bar{x}$ is the mean of those Euclidean distances.

They become the Grouping Test results and are highlighted in Table IV.

TABLE IV
GROUPING TEST RESULTS

Symbol	JASJAM	Tero 750	Touch Diamond
1	179.58	162.89	101.54
2	126.04	119.44	101.01
3	174.92	104.58	164.16
4	98.43	76.84	88.07
5	74.01	52.42	68.46
6	89.93	82.15	101.27
7	79.48	71.85	230.59
8	62.89	52.42	190.63
9	49.46	50.78	190.63
10	59.91	74.16	163.43
Average	99.47	84.75	139.98

The Tero 750 performs better than the other two phones in this test. The groupings for the capture symbols are smaller. This will be helpful as it reduces the possibility for the symbols to be wrongly decoded.

C. *Minimum Euclidean Distance Between Symbols Test*

Based on the reference points obtained in (2), the minimum Euclidean distance between each other is calculated using

(1). The Minimum Euclidean Distance Between Symbols Test results for JASJAM, Tero 750 and Touch Diamond are 28.10, 33.01 and 22.47, respectively.

This indicates that the captured symbols for Tero 750 are the furthest apart than the other two. This is good as for decoding downstream as it can tolerate more noise in the decoding process.

D. Summary of Results

From the results obtained in those tests, the ranking for the phones is summarised in Table V.

TABLE V
RANKING OF PERFORMANCE

	JASJAM	Tero 750	Touch Diamond
MCT[a]	1st	2nd	3rd
GT[b]	2nd	1st	3rd
MEDST[c]	2nd	1st	3rd

[a] Movement Colour Test
[b] Grouping Test
[c] Minimum Euclidean Distance Between Symbols Test

The Palm Tero outperforms the other two phones. However, it is also interesting to observe the file size of the images captured. The image file sizes are shown in the Table VI.

TABLE VI
FILE SIZE OF IMAGE CAPTURED IN KBYTE

Sample Number	JJ	PT	TD
1	76	168	171
2	76	201	193
3	74	211	186
4	71	202	151
5	71	166	180
6	88	168	186
7	106	167	174
8	90	213	167
9	84	167	172
10	86	161	179
11	99	162	166
12	107	176	181
13	88	177	144
14	82	204	177
15	85	166	194
16	101	165	178
17	109	169	151
18	97	170	163
19	96	174	180
20	94	167	177
Average	89	177.7	173.5

The JPEG compression is usually lossy and of various quality to cater for different files sizes. Although Tero has the best overall performance, it also had the largest average file sizes among the three phones. The quality of the JPEG compression is usually pre-set by the phone manufacturers or the camera software which the users have not control over.

In this paper, the quality of the images captured are pre-determined by the phone default camera software and there is no setting to make them similar. In order to have better control over the image quality, it will be more beneficial to understand the various image format that the developing software supported. For example, the WM supports various image format as shown in Table VII [4] and a BMP image has better image quality than the JPEG image. However, it will be larger in file size.

TABLE VII
IMAGES FORMAT SUPPORTED BY WM

Format	Description
JPEG	Joint Photographic Experts Group.
PNG 1.1	Portable Network Graphics format
TIFF	Tagged Image Format
GIF	Graphics Interchange Format
BMP	Microsoft Bitmap
EXIF	Exchangeable Image File Format
ICO	Microsoft icon file.

In additional, although the Touch Diamond is a newest phone equipped with the a biggest megapixels camera, it does not performed as well as the others. Higher pixel camera does not necessary mean that it is good in distinguishing the colour of the 2D barcode as generally phone camera are designed for scenery and not for capturing close up images [5].

IV. CONCLUSION

The Palm Tero 750 performs better than the other two phones. However, it is also noted that the captured file sizes are the largest among the three phones. It is a trade-off in terms of file size and performance. By having a better performance (as presented in Table V), it will provide a better platform for decoding a larger data capacity barcode (i.e. more smaller cells within the colour 2D barcode).

Similarly, a larger megapixel camera does not necessary mean that it is suitable for use as a colour barcode reader. In most case, those phone camera are designed for scenery and not suitable for close up images. Mobile phone developers for colour 2D barcode reader will need to consider the image format that they use and the suitability of the camera for close up images as both affect the capability of the decoding.

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