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The Use of Alignment Cells in MMCC Barcode

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***Abstract*—The QR code, a monochrome 2D barcode, is a popular and commonly used barcode system worldwide. QR codes can easily be read using a mobile phone with the appropriate decoder. As there is an increasing need for higher data capacity barcodes, some newer 2D barcodes, such as the MMCC code, have adopted the use of colour. However, the use of colour introduces more challenges for mobile phone decoders than with monochrome codes. In this paper, the use of alignment cells within the MMCC code is proposed to improve the robustness of the colour barcode when used in a mobile environment. With the addition of the alignment cells, the MMCC code is shown to achieve high data capacity even with a smaller physical size and the limitations of mobile phone cameras.**

I. Introduction

Traditional barcodes, such as the EAN-13 used for marking retail goods, typically contain a serial number as a key to a database. However, newer barcode systems are becoming portable databases themselves rather than just a key. As a result, we are witnessing the evolution of barcodes from one-dimensional to two-dimensional due to the need for much greater data capacity [1]. Among many others, two examples of such 2D barcodes as depicted in Figs 1 and 2 are the Quick Response (QR) code developed by Nippondenso IS System [2] and the Mobile Multi-Colour Composite (MMCC) code developed at Edith Cowan University [3].

QR codes are commonly used in Japan [4] and have started to become more popular in the West over the last few years [5]. In Japan, QR codes are widely used together with mobile phones equipped with QR code readers. According to a survey conducted in Jun 2009 by Marsh Inc, about 78.3% of the 300 participants were found to have such mobile phones [6]. QR codes are available in different physical sizes, ranging from small ones appearing on a burger wrapper to a large advertising banner hanging outside of a shopping mall, as shown in Figs 3 and 4 respectively. In the US, Google employs the QR codes in its Google Maps as shown in Fig. 5. Users with appropriate phones can access real time information about businesses that they have come across on the streets [7].

In theory, QR codes are able to encode up to a maximum of 2953 bytes of data [10] when the largest version (i.e. Version 40) is used. However, this is impractical in the mobile environment as each cell size will be very small and coupled with the blurring effects that are typically occur in images captured by mobile phone cameras, the decoder be very unlikely to be able to differentiate the cells. This results in most of the QR codes that are commonly employed to store only web links, as those links require only a small data size.

Fig. 1. An example of QR code

Fig. 2. An example of MMCC code

Fig. 3. An example of a small physical size QR code [8]

In order to fulfil the need to be a real portable datastore, instead of just a web link, some of the newer varieties of 2D barcodes such as the MMCC code, use colours to increase their data capacity.

With more colours being used, colour barcodes should have more data capacity than the equivalent monochrome types. But in practice, this is not always true as the effect

Fig. 4. An example of a large physical size QR code [9]

Fig. 5. An example of QR code being used [7]

of lighting on the colour is usually not consistent. Hence, accurate representation of the colour is often challenging and, as pictured in Fig. 6, the colour has a different hue of red value under different light intensities.

Together with the Joint Photographic Experts Group (JPEG) artifacts[1] that cause the image to be distorted, colour 2D barcodes become unstable in mobile decoding as accurately localising the barcodes and reading the correct value of the cells become challenging.

The purpose of this paper is to investigate the use of alignment cells in improving the robustness of colour 2D barcodes. With the improvement, the target is to demonstrate storage of more data than one of the most commonly used 2D barcodes in the mobile environment. Together with the alignment cells, the MMCC code[2] will be compared against QR code[3] in terms of maximum readable data capacity when used in the mobile environment.

This paper is organised as follows. A brief introduction of QR and MMCC codes have been provided in this section. In Section II, various factors contributing to the data capacity of the 2D barcodes when used in the mobile environment are discussed. The use of alignment cells in MMCC code and their benefits are highlighted in Section III. Comparison results between MMCC and QR codes can be found in Section IV and a conclusion in Section V.

[1]Currently, most mobile camera will save the images captured in JPEG, even though BMP and/or raw formats are also possible in some phones.

[2]MMCC code will be used to represent the colour 2D barcode

[3]QR code is used due to its popularity in the mobile environment. In future, more 2D barcodes will be compared.

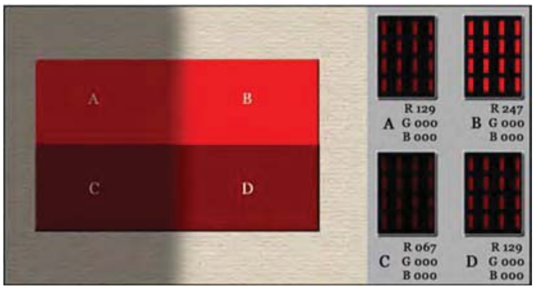

Fig. 6. Effect of lighting on colour value [11]

II. Data Capacity of 2D Barcodes in a Mobile Environment

Two common methods that are used to store more data in a 2D barcode are the use of more colours and a greater number of cells within the barcode. In the current state of the art for printing colour barcodes, the printing of small cells with multiple different colours is easily available. Colour printing resolutions of 1200 dpi can be commonly found in home-used inkjet printers, which indicates that high data colour 2D barcodes can be printed at a very low cost. However, the limitations to achieve higher data capacity for the barcode that is suitable for mobile phone cameras usually lay in the camera. Some of those limitations are discussed further in this section.

A. Increasing Data Capacity

By using more colours, the number of possible symbols will increase. Nonetheless, the Euclidean distances between the symbols will reduce, resulting in higher possibility of selecting the wrong symbols.

When more cells are to be incorporated into the barcode, it can be done either by:

- Increasing the physical size of the barcode while the cell size is fixed or
- Decreasing the physical cell area while the barcode size is fixed.

When the physical size of the barcode becomes large, the consistency of the colour representation values throughout the barcode varies as the amount of light illuminating on one part of the barcode may not be similar to another part.

In the event when smaller cells are used in the barcode, it poses a challenge for the mobile camera to differentiate the cells, especially for those cameras that are not equipped with an auto-focusing function.

B. Effects of Error Correction on Data Capacity

Unlike the 1D barcode, which has redundancy in its height, 2D barcodes will require forward error correction (FEC) to be embedded into the code. This FEC is even more critical when the image is captured by a mobile phone camera as more cells will likely be read wrongly, especially when the barcode image captured is distorted.

The increases in data capacity facilitate such ability. In the case of Reed Solomon codes, which both QR and MMCC codes use for their FEC, two Reed Solomon parity symbols are required to correct one symbol of error as highlighted in (1),

$$(n-k)/2 \tag{1}$$

where n is the total number of symbols[4] and k is the number of data symbols in the codeword [12].

This property indicates that the theoretical maximum error correction ability of Reed Solomon code is 50%. This happens when k is equal to zero. Thus, there is a limitation on the uses of FEC to counter all wrongly decoded symbols due to an increase in the number of colours and/or smaller cells. This imposes an upper limit on maximum achievable data capacity.

C. Effect of JPEG Compression

Usually, images captured by mobile phone cameras can be distorted due to the image file format used. In mobile phone cameras, images are mostly saved in JPEG format. This format uses a lossy compression [13] which is intended to significantly reduce the file size. This introduces a loss of image quality. Although, this compromise is usually acceptable to human eyes, as they are less affected by the loss of colour precision, this is not generally true for decoding a colour 2D barcode. This is because in colour 2D barcodes, sharp contrasts between the adjacent cells are required [14]. As the higher frequency components of the images are attenuated, this causes a smoothing effect on the chromatic information, leading to an undesirable image for decoding of the barcode.

This compression can affect the decoding of the barcode in two ways,

- Offsetting of the separation of the foreground (i.e. the barcode) and background (i.e. the quiet zone) of the image. This will result in errors in detecting the boundary of the barcode, which will lead to incorrect localising of the cells' centroid.
- When the cells are small, one cell's colour will affect the adjacent ones, leading to a loss in the precision of colours.

It is often challenging to obtain a clear separation between the foreground image and the background as portrayed in Fig. 7, which will cause the reading at the cells' centres to be offset. Together with the loss in colour precision, this causes undesirable errors in reading the barcode.

One method that is often used to overcome the JPEG compression artifacts is to have a barcode containing cells with large physical size. But this is not a good solution as the large cell size will significantly limit the data capacity.

III. Use of Alignment Cells

In order for the MMCC code to perform successfully with more cells in a mobile environment, the concept of an alignment pattern from QR Code [15] has been incorporated

[4]Both data and parity symbols.

Fig. 7. Close up of a JPEG image

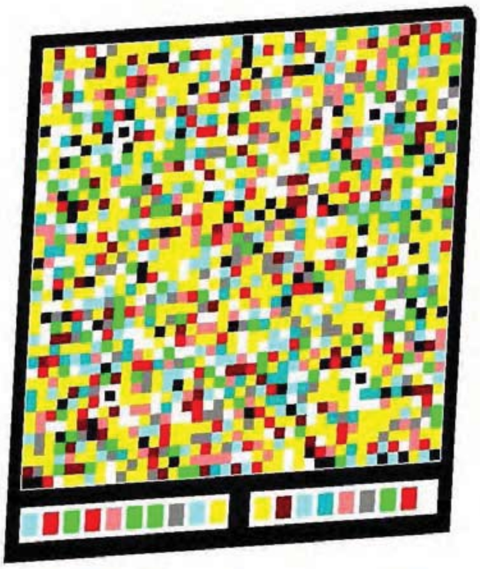

Fig. 8. Simulated capture image with top right hand corner chipped off

in this paper. Within the QR code, the alignment patterns are arranged at a fixed interval. Based on the differences between the estimated centre of the alignment pattern from the outer shape and the actual centre position, the mapping of the image can be corrected. This enables all the cells to be read in their centroids.

With the objective being to illustrate the advantage of deploying the alignment cells in the MMCC code, a barcode image of the MMCC code as pictured in Fig. 8 is created with the top right hand corner chipped off. This simulates the errors in locating the boundary of the barcode.

A. No Alignment Corrections Performed

When the alignment corrections are not performed, the resultant barcode image that is read by the decoder is highlighted in Fig. 9. Notice that the chipped off corner is not detected and reading of the cells occurs at a point offset from their centroid as indicated in the close-up image in Fig. 10. This offset caused many cells to be read at the wrong position.

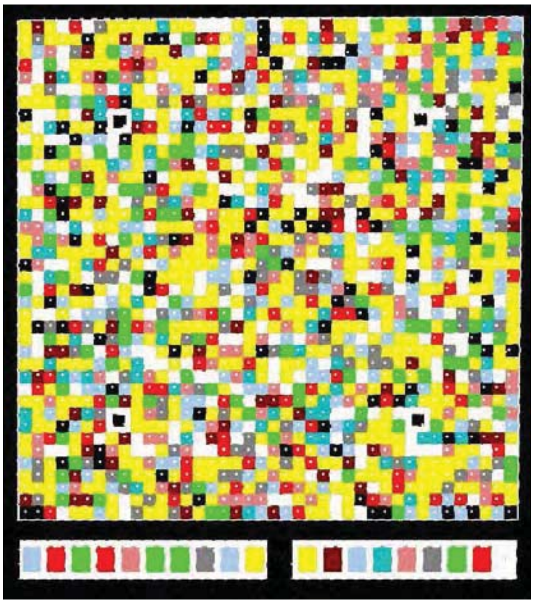

Fig. 9. Resulting barcode image without alignment corrections performed

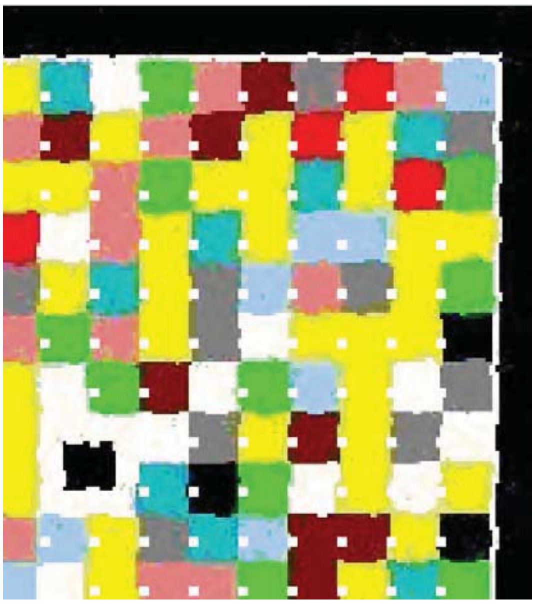

Fig. 10. Close-up image of Fig. 9

B. Alignment Corrections Performed

With the alignment cells, the variance between the physical cells' centroid and the centres obtained based on the boundary of the barcode are computed. Based on this variance, corrections can be applied to re-align the cells such that the centre of them can be read as shown in Figs 11 and 12. In Fig. 11, with the alignment corrections being performed, the chipped off corner can be detected and the cells can be read at the correct position. This resulted in a significant improvement in the robustness of MMCC code.

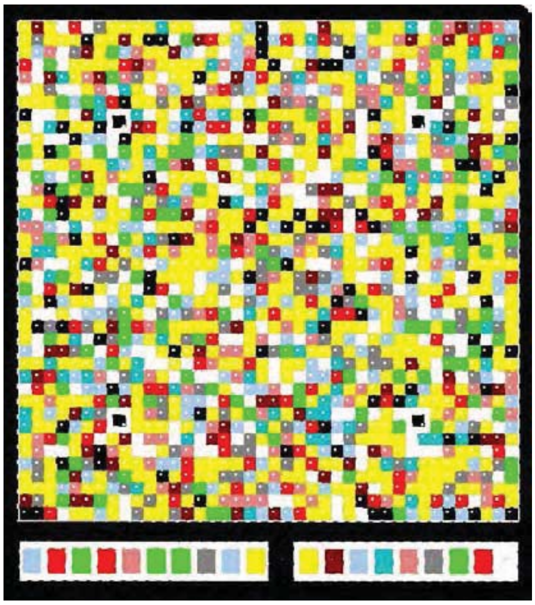

Fig. 11. Resulting barcode image with alignment corrections performed

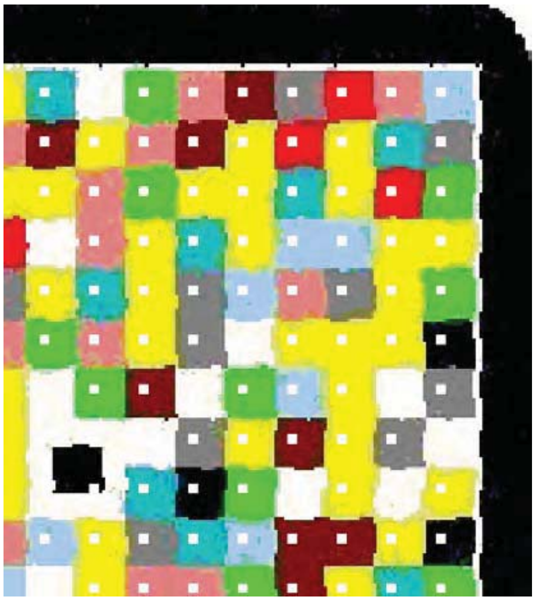

Fig. 12. Close-up images of Fig. 11

IV. Comparison Results between MMCC and QR Codes

With the robust improvement of decoding the MMCC code in the mobile environment, due to the use of alignment cells, more cells can be encoded into the MMCC code. With the improvement, the MMCC is compared against QR code in term of readable data capacity when used in the mobile environment.

The encoder of the MMCC code has been developed using MATLAB and the colour barcode is printed with a physical size of 30 mm by 33.75 mm as illustrated in Fig. 13. The QR code used is shown in Fig. 14. The physical dimension of

Fig. 13. Physical size of the MMCC code used in this paper, 30 mm by 33.75 mm

Fig. 14. Physical size of the QR code used in this paper, 31.82 mm by 31.82 mm

the QR code is 31.82 mm by 31.82 mm and it is generated by a commercial QR code generator[5]. For comparison, both barcodes share the same physical area of 1012.5 mm^2.

A. MMCC's Data Capacity

The error correction ability of the MMCC code is configured based on the length of message required to encode. When the message length is short, more cells will be used for error correction symbols. Similarly, when the length of the message is long, less cells will be available for error correction. This configuration is useful as most of the available cells will be used, ensuring less wastage of the cells and maximum reliability.

In this paper, a 40 by 40 cells MMCC barcode is configured with an error correction ability of 25%. With this configuration, the barcode can embed up to 316 bytes of data and is pictured in Fig. 13.

B. QR Code Configuration

In the configuration set by the QR code generator used, the version of the barcode depends on the length of the message and the minimum error correction selected. Since the error correction ability of MMCC code is set to 25%, the error correction setting for the QR code is fixed at Level Q (i.e. Quartile, 25%).

C. Decoders

The decoder used for MMCC is developed using Microsoft Visual Studio .NET Compact Framework environment with C#. This decoder is running on an HTC Touch Diamond, a Windows Mobile 6.1 phone, with a 3.2 mega pixel camera. As for QR code, the decoders are obtained from the list indicated

[5]BarShow by Jaxo Sytems, wersion 1.8.4 build 294.

TABLE I
PERFORMANCE OF THE DECODERS

Data size (bytes)	Ability to decode (MMCC decoder)	Number of QR decoders that are able to decode
60	Yes	6
70	Yes	6
80	Yes	2
90	Yes	2
100	Yes	2
110	Yes	1
120	Yes	1
150	Yes	1
180	Yes	1
210	Yes	1
240	Yes	1
250	Yes	0
270	Yes	0
300	Yes	0
316	Yes	0

TABLE II
CONFIGURATION OF QR CODES

Message size (bytes)	QR code version	Error correction ability (%)
70	6/Q	27
100	8/Q	27
240	13/Q	27
316	16/Q	27

in Mobile-Barcode [16] and QR Stuff [17] that are suitable to be used on the Touch Diamond. The following QR decoders are used in this paper,

- BeeTagg [18],
- i-nigma Reader [19],
- NeoReader [20],
- Okotag [21],
- QuickMark [22] and
- ScanLife [23].

D. Testing and Results

All the testing was conducted in an office lighting environment. The QR decoders will only indicated whether the barcode can be fully decoded or not, and not the amount of cells read correctly. Therefore, the MMCC decoder will use a similar methodology in this paper.

The performance of the decoders used is tabled in TABLE I. The MMCC decoder was able to successfully decode a colour barcode containing 316 bytes of data as shown in Fig. 13. As for the QR decoders, none was able to decode the similar message shown in Fig. 14. They were only able to successful decode data sizes ranging from 70 to 240 bytes. The configurations for the QR code when it is at 70, 100, 240 and 314 bytes are listed in TABLE II whereby the pictorial representations are illustrated in Figs 15, 16 ,17 and 14 respectively.

It is noted that as the data size get larger, the physical cell size reduces. Therefore, with larger data capacity, the decoder struggles to read the barcode. Comparing with the best performance among the QR decoder, the MMCC code outperforms QR code by about 32%.

Fig. 15. QR code with message size of 70 bytes and 27% error correction ability

Fig. 16. QR code with message size of 100 bytes and 27% error correction ability

Fig. 17. QR code with message size of 240 bytes and 27% error correction ability

The average decoding time for the QR code was within a second while MMCC took about three seconds. It shall be noted that MMCC code has not yet been optimised.

V. CONCLUSION

The use of alignment cells has improved the robustness of the 2D colour barcode when used in a mobile environment. This improvement results in a higher data capacity barcode. Therefore, MMCC code is shown to achieve a higher data capacity than one of the most commonly used 2D barcodes in a mobile environment. In future, more work will be done to investigate the stability of the alignment cells in MMCC code when more cells and colours are being used. Also, more comparisons with other 2D barcodes when used in a mobile environment will be studied.

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