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# The Use of Border in Colour 2D Barcode

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## Abstract

*In recent years, a trend has emerged in the use of colour to increase the data capacity of the 2D barcode. However the decoding of such colour barcode can be challenging in a mobile environment due to blurring effect that is commonly found in images captured by camera mobile phone. Blurring affects the synchronisation between the cells. It also causes the colour value of the cell to be wrongly interpreted. Hence, this paper proposes the use of border to improve the synchronisation and decoding. Three different types of border and the choice of its width will be investigated.*

**Figure 1. An example of the High Capacity Colour Barcode (HCCB).**

## 1. Introduction

The two dimensional (2D) barcodes have been developed to enhance the capability of the traditional one dimensional (1D) barcode, especially in data capacity [2]. The increase of data capacity enables 2D barcodes to improve the data robustness to errors, allowing them to encode extra data for error correction [4]. While the 1D barcodes have redundancy in the vertical direction, this does not exist in the 2D barcodes. Hence, the error correction ability is important for the 2D barcodes since they can be damaged due to being smudged, crumbled, torn 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 size. An example of such barcode is the High Capacity Colour Barcode, or HCCB in short. This is shown in Figure 1 [3].

By using more colours, the data capacity increases. However, the euclidean distance between the possible symbols will be smaller. Thus, the chance of selecting the wrong symbol increases.

In addition, the colour barcodes can be potentially unsuitable for mobile applications. It is because the cells might not be decoded properly when the image of the barcode is blurred. Blurring also affects the synchronisation between the cells. Such blurring is often found in images captured by camera mobile phone.

The use of white border in HCCB assists the decoding

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of the colour barcode. It is used to contain the cells when captured as an image. Without the border, the colour cell will seem to be enlarged and merged into the adjacent cells [3].

### 1.1 Organisation of This Paper

This paper is organised as follows. A brief introduction is provided in Section 1. In Section 2, an example of a colour Matrix Code is shown. This example will be used as a base for comparison between different types of border. Different types of border are discussed in Section 3. Section 4 presents the effects of the border's thickness, while the conclusion can be found in the Section 5.

## 2. Example of the Colour 2D Barcode

The 2D barcode can be broadly classified into two types: stacked symbology and matrix code [1]. Stacked symbology, also known as multi-row code, is more accurately applied to those symbologies made up of a series of 1D barcode. The data is coded in a series of bars and spaces with varying width. As for the matrix code, it applies to a 2D barcode that coded the data based on the position of spots within the matrix. Each element is similar in dimension, and the position of the element codes the data.

In this paper, a $9 \times 9$ colour barcode that belongs to the Matrix Code will be used as a base for illustrations and comparisons. The colours used are shown in Table 1. They are resulted from varying the value of the three primary colours, Red, Blue and Green. In this paper, this barcode is known as the Base Barcode and it is shown in Figure 2.

**Table 1. The eight colours used in the Base Barcode.**

| | Red | Green | Blue |
|---|---|---|---|
| Black (K) | 0 | 0 | 0 |
| Blue (B) | 0 | 0 | 1 |
| Green (G) | 0 | 1 | 0 |
| Cyan (C) | 0 | 1 | 1 |
| Red (R) | 1 | 0 | 0 |
| Magneta (M) | 1 | 0 | 1 |
| Yellow (Y) | 1 | 1 | 0 |
| White (W) | 1 | 1 | 1 |

## 3. Border

Three different types of border have been proposed. These are called White Border, Furthest Border and Focus Border. The borders are created using MATLAB and their

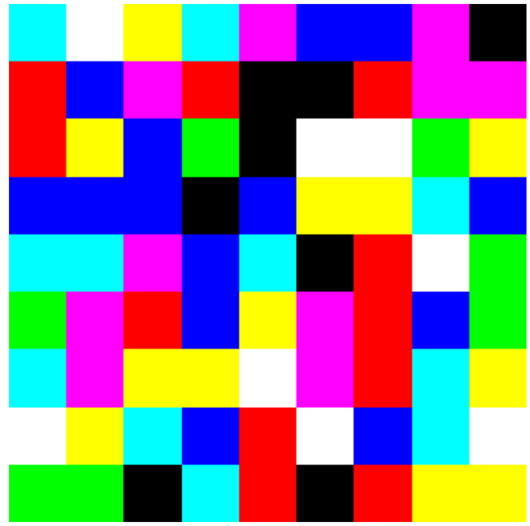

**Figure 2. Example of a colour 2D barcode.**

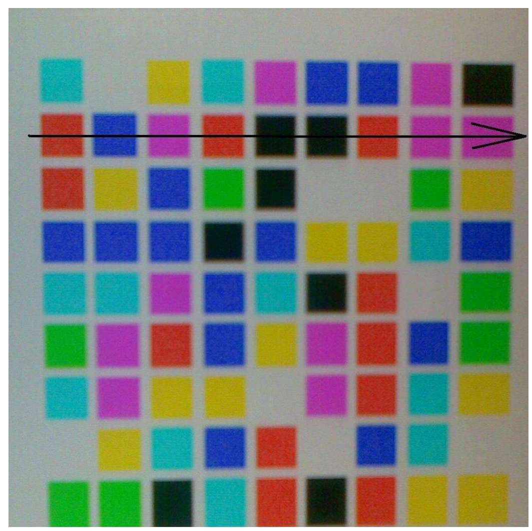

**Figure 3. A captured colour 2D barcode and the direction for reading the cells in the $2^{nd}$ row.**

widths are fixed at 20% of the total width. The total width refers to the width of the cell and the border itself. Thereafter, the images of the respective borders are captured using camera mobile phone. An example is depicted in Figure 3. The $2^{nd}$ row of the barcode is chosen to test the synchronisation and decoding capability. The arrow indicates the direction of the cells that are read.

The $2^{nd}$ row's RGB values of the Base Barcode (i.e. barcode without border) is shown in Figure 4. From the graphs shown, it can be seen that the clock timing is not embedded into the barcode. Hence, if there is a long chain of similar

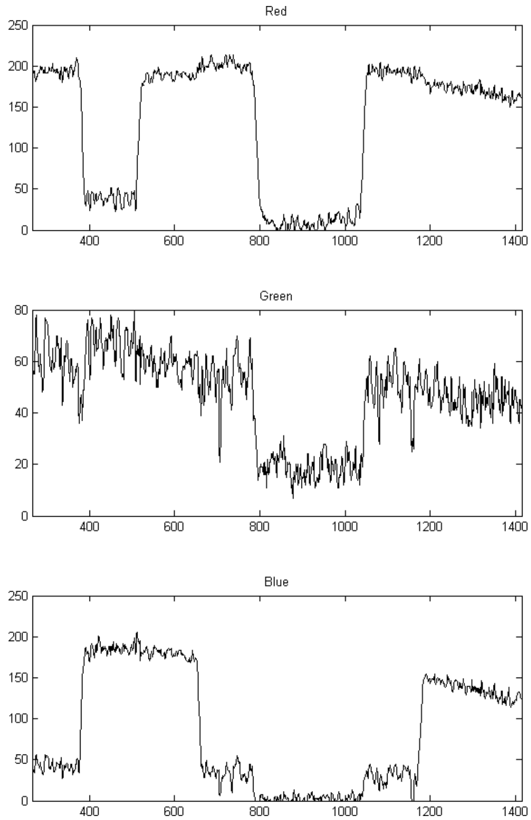


**Figure 4. RGB values of the 2$^{nd}$ row of the Base Barcode.**

colour cells, the synchronisation for the decoding will be lost.

### 3.1. White Border

As the name suggests, the White Border uses white for its border. This is shown in Figure 5.

Out of the eight colours shown in Table 1, black and white are usually more stable than the rest. Their values do not vary as much as compared to the others when it is used in different lighting environments. Therefore, both colours are considered suitable to be used for border. Nevertheless, only the white is considered here.

The RGB values of the White Border are displayed in Figure 6. The use of white for the borders distinctively separated the cells as compared to the Base Barcode. With this, there is an embedded timing as there are transitions between each cell unless there are two or more consecutive white cells being used.

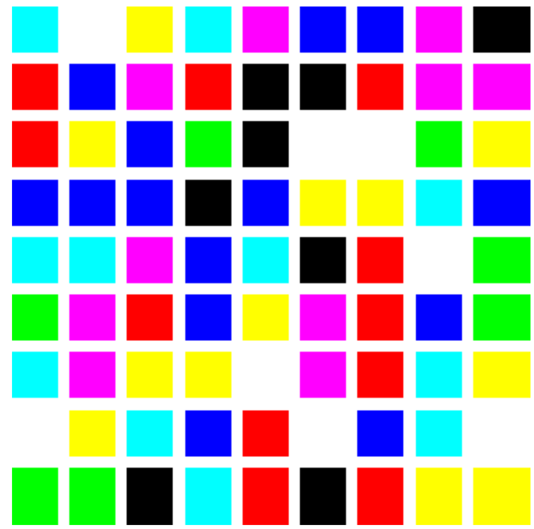

**Figure 5. White Border.**

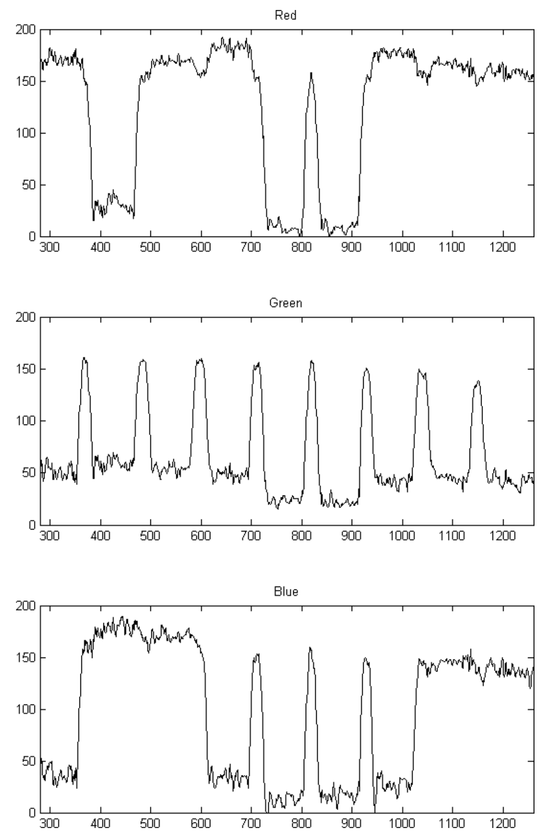


**Figure 6. The RGB values of the White Border.**

### 3.2. Furthest Border

In the Furthest Border, the colour of the borders are determined using the "furthest colour" from the two adjacent

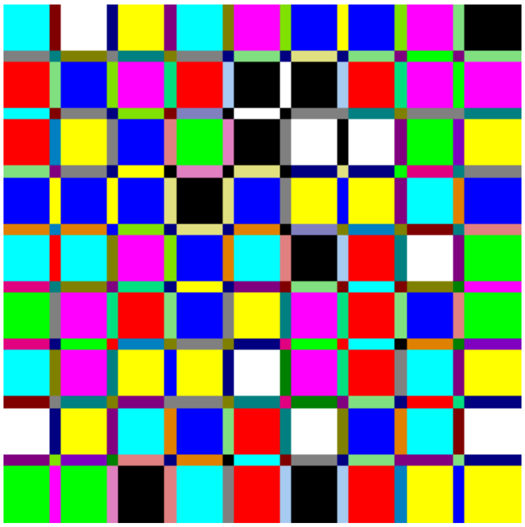

**Figure 7. Furthest Border.**

cells in the RGB colour space representation. The border colour is calculated as

$$R_{border} = [not(R_1) + not(R_2)] \times \frac{255}{2} \qquad (1)$$

where $R_{border}$ is the red component of the border while $R_1$ and $R_2$ are the logical values for the adjacent cells.

The values for both the green and blue components of the border are also determined in the similar way.

$$G_{border} = [not(G_1) + not(G_2)] \times \frac{255}{2} \qquad (2)$$

$$B_{border} = [not(B_1) + not(B_2)] \times \frac{255}{2} \qquad (3)$$

The Furthest Border and its results are shown in Figures 7 and 8 respectively.

This type of border is good for synchronisation as there will always be transitions in all the three primary colours. If any of the colour components of the adjacent cells are the same, there will be a "spike" in that component. In the case whereby the colour components are different, there will be a change in the state (i.e. high to low or low to high). With these transitions, the clock is embedded into the code which is good for synchronisation.

The number of possible border colours is dependent on the number of possible colours for the cell. For example, if there are eight different colour cells, then there are 25 border colours. When the number of possible cell colour becomes large, the number of possible border colour becomes unmanageable. Furthermore, as there are more border colours, the euclidean distance between the each colour will be smaller. Thus, the chance of selecting the wrong colour by the decoder will increase. Therefore, this type of

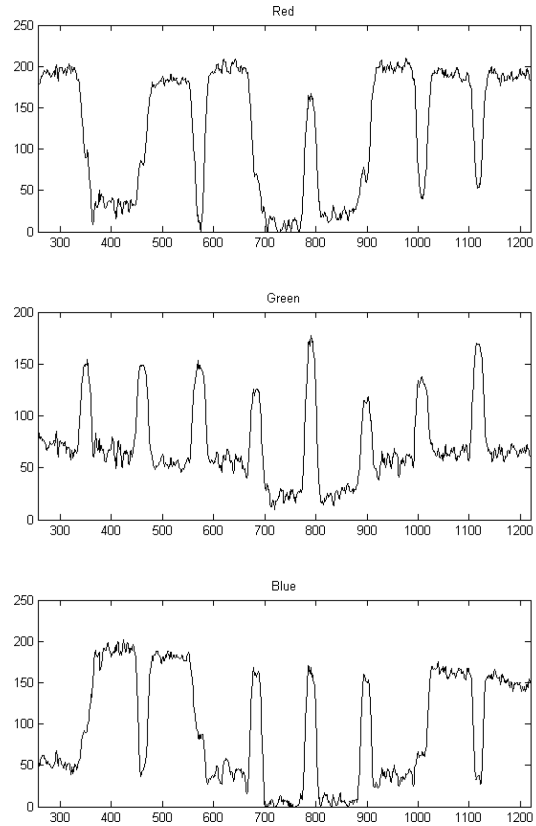


**Figure 8. RGB values of the Furthest Border.**

border is only recommended for small number of possible cell colour.

### 3.3. Focus Border

From the images captured by the camera mobile phone, it is commonly observed that the red and magenta are closer to each other. Similar observation is made in the case for blue and cyan. Hence, the euclidean distance between these pairs of colours are smaller as compared to the rest. The White Border and Furthest Border do not help in these cases. Although the Furthest Border can be used to determine the colour of the adjacent cells, it can only assist when the number of cell colour is small.

Hence, in the Focus Border, more emphasis are given to red, magenta, blue and cyan so that they can be easily differentiated. The rules for constructing this type of border is as follows:

1. When both adjacent cells are of the same colour, the border will be the "furthest" colour in the RGB colour space representation. This is to prevent the lost of synchronisation due to the long chain of similar colour cells.

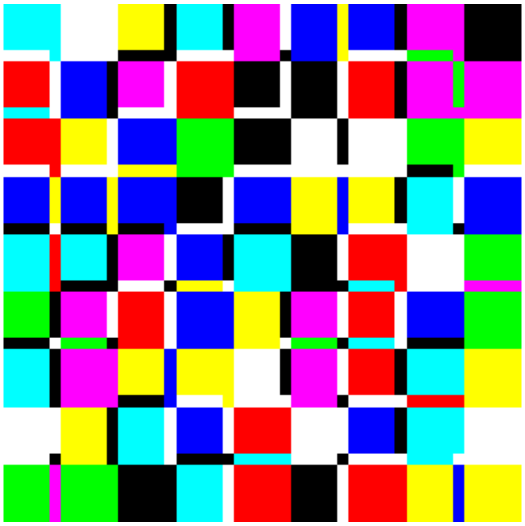

**Figure 9. Focus Border.**

2. Then if the $2^{nd}$ cell is either red or blue, the border will be set to white,
3. or if the $2^{nd}$ cell is either magenta or cyan, the border will be black.
4. In the case whereby the $2^{nd}$ cell is none of the above (i.e. black, green, yellow or white), the border will be similar to the $1^{st}$ cell. Hence, it will appear as if there is no border.

Table 2 summarises the above rules. The Focus Border is shown in Figure 9.

**Table 2. Table for Focus Border.**

| | 2nd Cell | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1st Cell | K | B | G | C | R | M | Y | W |
| Black (K) | W | W | K | K | W | K | K | K |
| Blue (B) | B | Y | B | K | W | K | B | B |
| Green (G) | G | W | M | K | W | K | G | G |
| Cyan (C) | C | W | C | R | W | K | C | C |
| Red (R) | R | W | R | K | C | K | R | R |
| Magneta (M) | M | W | M | K | W | G | M | M |
| Yellow (Y) | Y | W | Y | K | W | K | B | Y |
| White (W) | W | W | W | K | W | K | W | K |

In the graphs shown in Figure 10, there will be transitions in at least one of the primary colour. These can be used for the clock timing. Also, the use of such border can determine the values of the adjacent cells.

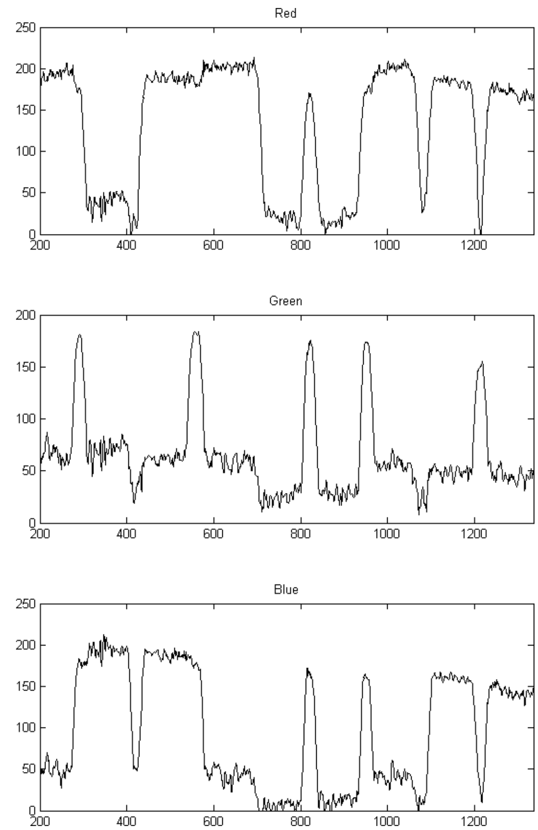


**Figure 10. RGB values of Focus Border.**

### 3.4. Comparison of the Three Proposed Borders

The comparison study of the three borders in their ability to embed clock timing for synchronisation, and their ability to determine the values of the adjacent cells are summarised in Table 3.

**Table 3. Comparison of the three proposed borders.**

| | Clock timing | Determine Value |
|---|---|---|
| White Border | Yes | No |
| Furthest Border | Yes | Yes (limited cell colour) |
| Focus Border | Yes | Yes |

## 4. Width of Border

Blurring is often found in images captured by camera mobile phone. Hence, the selection of the width for the border will have an impact on the decoding. In this paper, three different choices of border width will be discussed. These

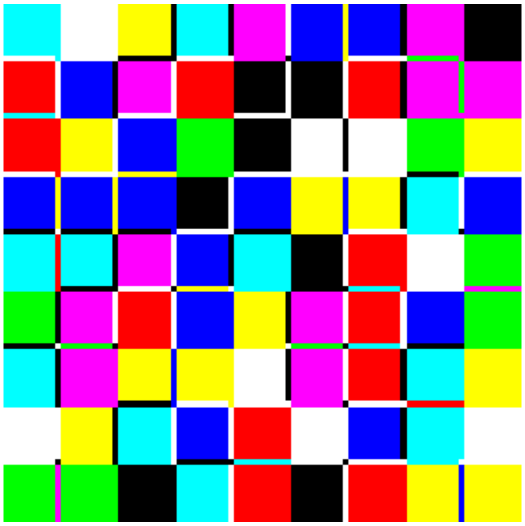

**Figure 11. 10% Width Border.**

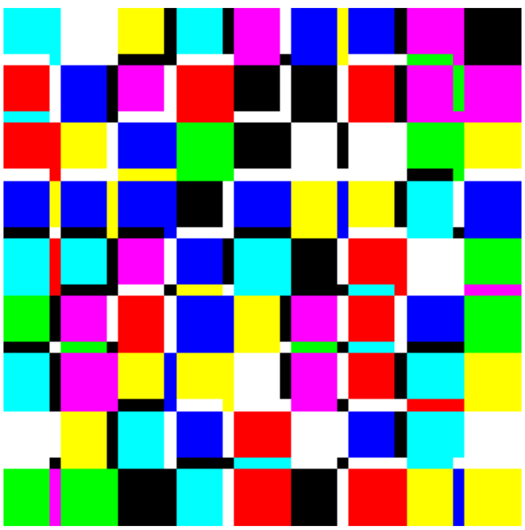

**Figure 12. 20% Width Border.**

are referred as 10% Width, 20% Width and 30% Width. Using the Focus Border, the above widths are shown in Figures 11, 12 and 13 respectively.

The captured results for the three widths are presented in Figures 14, 15 and 16.

As can be seen in Figure 14 for the 10% Width, the "spikes" are not distinctive. If this is used in the mobile environment whereby the image becomes blurred, these "spikes" might not be detected. In the case of the 30% Width, the width of the border is almost similar to the cell. The decoder might interpreted the border as a cell. Hence, the 20% width is considered good trade-off for the mobile environment.

**Figure 13. 30% Width Border.**

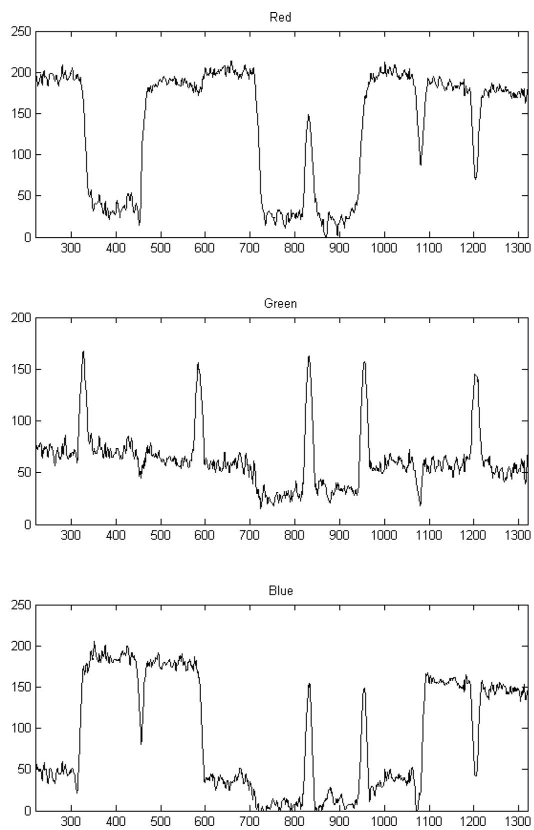


**Figure 14. RGB values of 10% Width.**

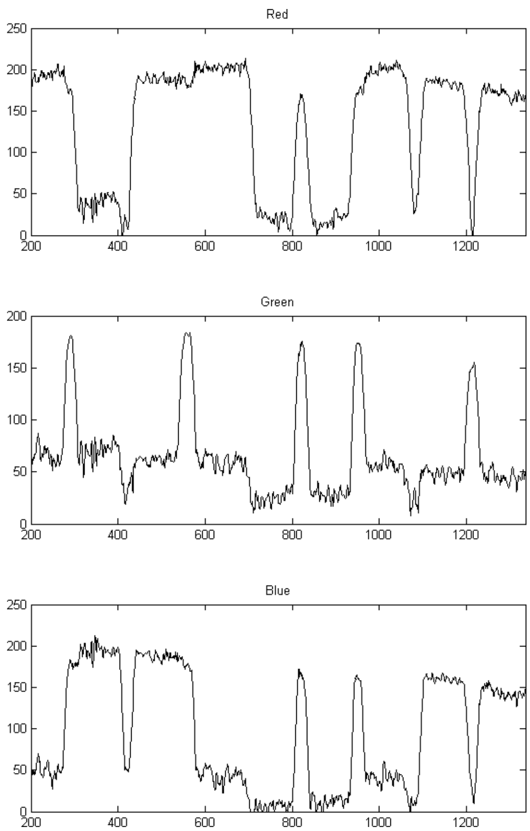


**Figure 15. RGB values of 20% Width.**

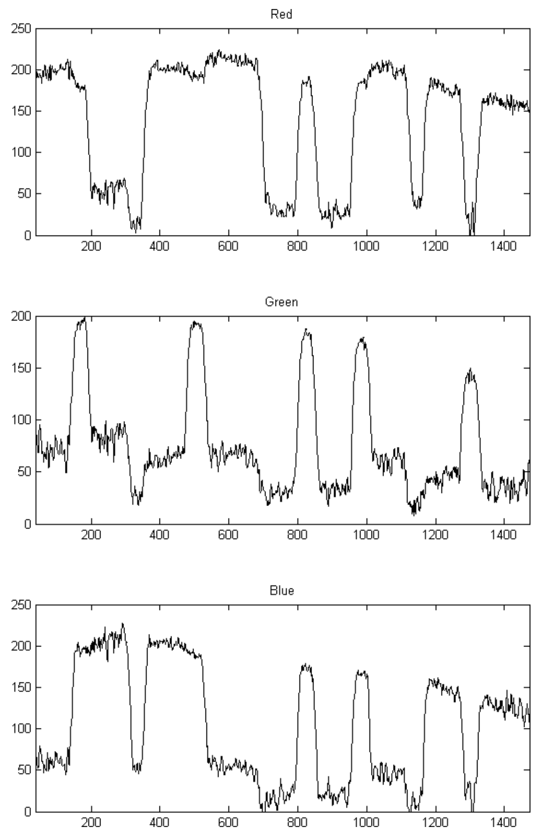


**Figure 16. RGB values of 30% Width.**

## 5 Conclusion

The choice of the colour and the width of the border will determine the performance of the barcode. A suitable border will provide a better platform for usage in the adverse mobile environment. In such environment, it is recommended that a 20% Width is used for the border. Similarly, it is important to have a balance in performance between synchronisation and the ability to determine the correct adjacent colour cell. Therefore, the Focus Border is considered more suitable for use in the colour 2D barcode.

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