1-1-2010

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10.1109/WMUTE.2010.45
This is an Author's Accepted Manuscript of: Tan, K. , & Chai, D. K. (2010). A new perspective on first read rate of 2D barcodes in mobile applications. Proceedings of IEEE International Conference on Wireless, Mobile and Ubiquitous Technologies in Education. (pp. 192-194). . Kaohsiung, Taiwan. IEEE. Available here

A New Perspective on First Read Rate of 2D Barcodes in Mobile Applications

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Abstract

The first read rate (FRR) has been one of the traditional benchmark metric for measuring the performance of barcode systems. In recent studies, it has been noted that the FRR alone is not a complete measure of user experience, especially of barcodes in mobile applications. In this paper, we present a further three factors that would influence the user experience of mobile 2D barcodes. Our investigation is based on a quantitative survey of a controlled study participated by 250 lay users of mobile phones, through reading QR Code and Data Matrix barcodes with a variety of camera mobile phones. Observations from our study correlate well with findings from other works.

1. Introduction

The forever developing mobile phone industry has seen the integration and development of digital imagery for mobile devices. It has become a standard expectation that every mobile phone purchased is equipped with an inbuilt digital camera. This development in mobile technology has paved the way for the application of 2D barcodes. A mobile phone, with its camera and display screen, can simply be viewed as an input-output device with network connectivity. As the camera and barcode technologies improve, more substantial amount of data can be encoded onto a 2D barcode, resulting in many more innovative applications, which can be used in learning and teaching as well as social interaction. As more 2D barcodes are invented, there is a need for a suitable metric to evaluate these new designs and their user experience. The first read rate has been one of the traditional benchmark metric for measuring the performance of barcode systems.

The first read rate (FRR) is a ratio of the number of successful reads on the first attempt to the total number of first attempts. A good barcode should offer a FRR that is greater than 85% and a second pass read rate of 95% [1]. Barcodes with a low FRR must be read a number of times before a successful read can be achieved.

The FRR is also a measure of reliability and to some extent, user experience. For instance, low FRR will frustrate user, which often translates to user refusal to barcode usage. Thus, the FRR is often used to gauge user experience of a barcode system, particularly of 1D barcode type. However, recent research [2] has found that the FRR is not very useful in measuring and distinguishing the user experience of 2D barcodes in mobile phone applications.

Hence, an improved metric is required to benchmark mobile 2D barcodes. This paper investigates on what other factors that need to be considered when developing such metric. This paper is organized as follows. The factors affecting the user experience of mobile 2D barcodes are presented in Section 2. The setup of the quantitative survey study is detailed in Section 3. Section 4 presents the results and discussions, while the conclusion can be found in Section 5.

2. Factors affecting user experience

We have observed that other than the traditional measure of FRR[1], other factors that can significantly affect the readability of mobile 2D barcodes and consequently user experience include:

- The cell size of the 2D barcode symbol, which is directly related to the readable distance of the barcode. We shall call this factor α.
- The software decoder of the 2D barcode, which is dependent on the camera phone platform it is implemented on, e.g. J2ME, C++ on Symbian, etc. We shall refer to this factor as β.
- The hardware capability of the camera phone, e.g. auto focus, macro lenses, zooming function, etc. We shall call this factor γ.

Exactly how each of these factors affects the readability and user experience of the mobile 2D barcode is the research question that will be addressed in this paper.

3. Experimental setup

The study involved 250 participants whom were randomly chosen university students, staff and visitors.

[1] The FRR of the barcodes used in our studies are all 100% read under our experiments conditions.

978-0-7695-3992-8/10 $26.00 © 2010 IEEE
DOI 10.1109/WMUTE.2010.45

The experiment was held over 12 different sessions across various campus locations, over a period of three months. To ensure independence of any environmental condition on the outcome of our study, we have conducted half of the sessions in an indoor environment, while the other half was conducted in an outdoor setting.

Figure 1. An example of QR Code (left) and Data Matrix (right) symbologies.

The camera phones used in this study were the same phones used in the research previously reported in [2]. The two 2D barcode symbologies used in the study were the QR Code [3] and the Data Matrix [4], as depicted in Figure 1[2].For each barcode type, we have asked the participants to read from a large symbol of size 5 cm × 5 cm as well as a small symbol of size 2.5 cm × 2.5 cm. For each symbol size, the participants were asked to capture the barcode with their mobile camera phone from both a close distance of 30 cm away and a far distance of 60 cm away, both under ambient light and another when the barcode is illuminated by a 60W incandescent globe. Participants were also required to read the barcode symbols using different digital zoom settings on the respective camera phones.

A questionnaire was developed to gauge each participant's experience in reading each barcode symbol from the different distances, under different lighting conditions. The demographic data of the participants are given in Table 1.

To test the difference in the software decoder, we used both the Kaywa reader, which is a C++ on Symbian implementation that reads both the QR Code and Data Matrix, and the J2ME Semacode reader, which can read Data Matrix, as used in [2].

4. Results and discussions

4.1. The α factor: cell size of 2D barcode symbol

From our questionnaire, we uncovered that 98% of the participants had found the QR Code symbology, with its more distinctive finder pattern, easier to decode when compared to the Data Matrix symbology, where its finder pattern is relatively less prominent. Furthermore, 95% of those who preferred the QR Code found that reading the 2D barcode symbol at the closer distance (30 cm) from the barcode symbol, thus, have a relatively bigger data cell image, produced the most instances of successful reading. Such findings are consistent across both sets of experiments, with and without the incandescent lighting.

This observation suggests that the size of a 2D barcode finder pattern and data cells (the α factor) is of significant importance to the quick and successful reading of a given 2D barcode symbol, which then translates to a better user experience of this barcode.

The importance of the α factor for successful mobile 2D barcodes is not a surprising finding as recent novel colour 2D barcodes designed for camera mobile phones, such as the ColorCode [5] and the Microsoft Tag [6], have opted for bigger data cell sizes in lieu of achieving a higher data density; even though for their 300 dpi variety [7] (in the case of the Microsoft Tag), they can store much more data using very small data cells.

4.2. The β factor: the dependency on the software decoder

There is a marked delay of about two seconds in the reading operations of the J2ME Semacode reader, while the Symbian-based Kaywa reader is much faster. Surprisingly this delay made no significant difference to the overall observed user experience. Only 57% of the participant preferred the Kaywa reader over the Semacode reader for reading the same Data Matrix barcode. According to the comments from the participants, this indifference seems to be attributed to their willingness to wait if the reader can eventually decode the barcode successfully. If it is not too long, this delay is often deemed acceptable by the general lay user. Also from our results, it seems that the top peeve of the general lay user (at 97%) is when the reader continued to fail after many attempts in different reading position. This observation correlates well with our finding as reported in [2] where it was observed that while different reader software has different operating speeds, a reader that actively assist the user in capturing a given 2D barcode symbol for decoding can make a difference in the user experience. Hence, the β factor is not a significant contributor to the user experience for a given mobile 2D barcode, unless this factor is at its either extremes, which is either complete failure or actively assisting the reading process.

2 Due to limitation of allowed space, the readers are referred to literatures [3] and [4] for further information on these two barcodes.

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A questionnaire was developed to gauge each participant's experience in reading each barcode symbol from the different distances, under different lighting conditions. The demographic data of the participants are given in Table 1.

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[2] Due to limitation of allowed space, the readers are referred to literatures [3] and [4] for further information on these two barcodes.

Table 1. Demographics of the participants involved in the quantitative study.

Participants		Age Group								Total
		18-22	23-27	28-32	33-37	38-42	43-47	48-52	53+	
Gender	Male	66	74	10	5	4	1	3	4	167
	Female	48	23	5	3	1	1	0	2	83
Mobile Phone Ownership	Yes	114	95	15	8	4	2	3	5	246
	No	0	2	0	0	1	0	0	1	4
Smart Phone Ownership	Yes	26	27	3	2	1	0	2	1	62
	No	88	70	12	6	4	2	1	5	188
User Proficiency in Mobile Barcode Reader	Used Before	7	11	1	1	0	0	1	0	21
	Never Used	107	86	14	7	5	2	2	6	229

4.3. The γ factor: the differences in the image capturing hardware of the decoder

The two camera phones used [2] in this study have a different degree of digital zoom, where the Nokia 6600 has a 2× digital zoom and the Nokia 6630 has a 6× digital zoom. Under ambient light condition, 78% of the participants found that the greater digital zoom capability in the Nokia 6630 made a significant difference to their experience in capturing the barcode symbols. Under the illumination of an incandescent light source, only 64% of the participants have the same experience. In fact, with the incandescent light source, 6% of the participants found that the glare afforded by the artificial light had caused a larger than usual number of reading errors on the Nokia 6630 handset.

This observation compares well with the factor α observation, at least for the case of the digital zoom. Obviously under greater zoom, the resultant finder pattern and data cell size will be greatly magnified. Nonetheless just as in any analogue amplification system where noisy data are amplified, often the noise of the system is also amplified by the same magnitude. The error observed in the Nokia 6630 under incandescent light can be attributed to this phenomenon. The advantage of the greater digital zoom in the Nokia 6630 over the Nokia 6600 was also observed in the experiments reported in [2].

Hence, the γ factor is a comparable importance to the α factor but such an importance saturates at an upper limit, where any further improvement in the hardware capability of the decoder is limited by the operating constraints and limitations of the 2D barcode.

5. Conclusion

From this study, we have made the following observations. Firstly, the FRR metric is often not sensitive enough to capture the factors that further influence the user experience of a 2D barcode in mobile application.

Secondly, the size of the finder pattern and its data cells, the α factor observed herein, is proportionally related to the user experience of a given mobile 2D barcode.

Thirdly, within reasons, the differences between the reader software platforms, the β factor observed herein, do not significantly influence the user experience, unless at the extreme ends of the spectrum of the user experience.

Finally, improvement in the hardware image capturing platform, the γ factor observed herein, will also significantly improve the user experience, but this improvement is limited by the operating constraints and limitations of the barcode.

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