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Study on a model for perceived text definition of multi-stroke Chinese character

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Abstract. IS0-13660 has defined line attributes in digital prints. In order to investigate the effect of these attributers on perceived text definition (PTD), the correlation model between the two was developed in this study. The test target with a multi-stroke Black Type Chinese character in two sizes of 6.5 and 10.5 points, as well as some single lines, was designed and printed, coming into being 16 test samples with different qualities. The objective line attribute measurements and subjective definition evaluations were carried out, and linear correlation model was built between the two. The experimental results indicate that the PTD could be relevant to line's contrast, raggedness, blurriness and width, and is always positively relevant to the contrast and negatively relevant to the later three attributes.

Introduction

Print quality is paramount in determining customer satisfaction. And there is different methodology, such as objective and subjective ones, to reach the aim. ISO-13660 [1] has built an objective evaluation system on digital print text and graphic image quality (e.g. five important attribute parameters for line and character). The question is then how these objective attributes affect the human eye's perception to prints quality? It is not revealed in the ISO standard, but will be decisively an application issue.

In this study, some single lines and a multi-stroke Black Type Chinese character in two sizes were inspected objectively and subjectively. Further, a correlation model between the perceived text definition (PTD) and line attributes was built and analyzed.

Line attributers in digital prints

For line and character prints, ISO-13660 has defined five important attribute values, which are line width, raggedness, blurriness, density and contrast.

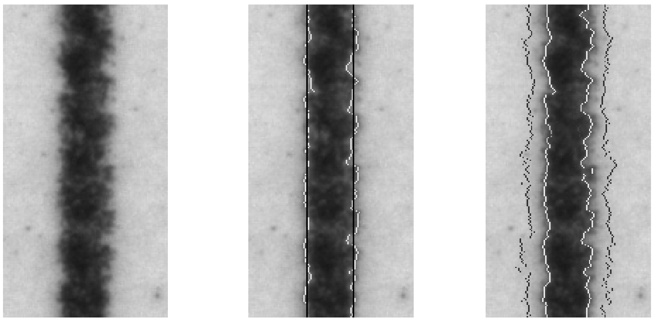
A digitized image of a printed line is shown in Fig.1(a). It could be seen that the inner of the line was not the same solid, and border was no longer smooth or straight as its nominal. Actually, the optical reflectance would gradually change with locations alone a line perpendicular to the line direction, no longer being a break border.

Hereby, some characteristic points defined by ISO-13660 are explained, and their definitions and reflectance factors are as follows:

$$\rho_V = \rho_{max} - (\rho_{max} - \rho_{min}) \cdot V\% \quad (1)$$

where V varies from 0 to 100, ρ_{max} and ρ_{min} are maximal and minimal reflectance factors respectively, corresponding to that on the background and the inner of line.

According to this, the point with V=60 is defined as edge threshold one, and the points satisfied this condition in Fig.1(a) constructed the two light ragged lines, shown in Fig.1(b). The points with V=90 and V=10 are inner and outer boundary edges respectively, their resulting points for Fig.1(a) were the two light and the two dark ragged lines shown in Fig.1(c).



(a) (b) (c)

Fig.1 Image of a scanned digitally printed line

Then five line attributes are defined as follows:

1) Line width-width of the line measured normal to the line from edge threshold to edge threshold, such as the two dark lines in Fig.1(b).

2) Raggedness-standard deviation of the residuals from the line-width line to the edge threshold of the line (calculated perpendicular to the line-width), named as R hereafter.

3) Blurriness-average distance between the inner and outer boundary edges, named as B hereafter.

4) Darkness-mean density within the ρ_{75} boundary edge, named as D hereafter, where $D = -\log_{10} \rho$.

5) Contrast-it defined as

$$C = (\rho_{max} - \rho_{min}) / \rho_{max} \quad (2)$$

Test target's printing and its attribute measuring

Firstly, a pattern, which included a multi-stroke Black Type Chinese character in sizes of 6.5 and 10.5 points and some single lines with widths equivalent to that of strokes in the characters, was designed as a test target for line attributes measurements and visual evaluations of text definitions. The image of the pattern is shown in Fig.2.

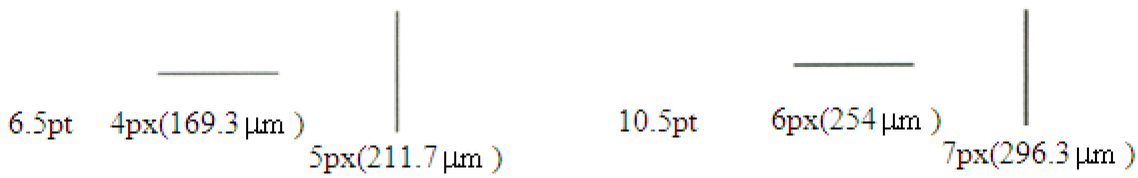


Fig.2 Test target (shown at 1.5 multiple)

Some types of printers were selected, including laser, ink-jet, as well as digital press. A common property was that they had the same output resolution of 600dpi. So, same pixels could be assigned to a designed width on these printers when outputting. Meanwhile, some types of papers, special and non-special ones, coated and non-coated ones, etc., were bought on the market and used.

Then, the test target was made into a digital image file with a resolution of 600dpi, so as to match the output resolution. And here, the widths of horizontal and vertical strokes in the target characters with 6.5 point size were equivalent to that of 4 and 5 pixels (169.3 µm and 211.7 µm , abbreviated as 4px and 5px), as shown in the left half part of Fig.2. In case of 10.5 size text, the results were as in the right half part of Fig.2.

For cyan text, the target image were printed out on every printers with all the papers selected, altogether getting 36 test samples.

A CCD camera-based system [2] acted as an image acquisition device to digitize the test samples, and line attribute parameter values were measured for 4px-7px single lines.

It was found that there always some similar attribute values appeared, no matter for which attribute, no doubt resulting in some insignificant data. Throwing away these data and 16 sets of attribute data, or samples, were leaved and used in our experiment at last.

Subjective evaluations

The accepted subjection evaluation was a pair-wise comparison method, sorting the 16 samples from the best to the worst by series of one by one comparison. Here the process conducted in a standard lighting box, which had a D65 illuminant with an illuminance of 1500lx.

Each viewer was at the distance 35cm away from the sample, and was asked to give a score to sample's text definition according to his perception. Where 0 score means very blur and absolutely illegible, 6 score implies a little blur but receivable, 10 score then signifies very clear and perfect. Any other scores within 0-10, even decimal fraction, could be given, basing on his perception.

Nineteen observers with normal eyesight, ten men and nine women, were chosen to make out the evaluations, and two sets of visual scores of them were deleted because of big errors by PF/3 factor analysis [3]. Then the mean values of all the leaved seventeen sets of score data were calculated to represent the perceived definition scores for the sixteen samples.

Models of PTD

A quality factor Q was defined to represent the human PTD. And assuming that this Q was linearly relevant to the line attributes. It was found that line contrast was linear associated with its optical density. So, the two parameters were regarded as the same effect on Q. And Q was further assumed to linearly relate to the four line attributes, which were C, R, B and W, as shown in Eq.3.

$$Q = \alpha_1 \cdot C + \alpha_2 \cdot R + \alpha_3 \cdot B/100 + \alpha_4 \cdot W/100 \tag{3}$$

where $\alpha_1 \sim \alpha_4$ were underdetermined correspondence coefficients. Additional, because the B and W usually have values of one hundred times of that in C and R, then the B and W were all firstly divided by 100, so as to having the same value order of magnitude in them.

From the experimental data, models were made out for two size characters as below:

$$Q_{6.5pt} = 18.17 \cdot C - 0.01 \cdot R - 0.48 \cdot B/100 - 1.03 \cdot W/100 \tag{4}$$

$$Q_{10.5pt} = 19.18 \cdot C - 0.09 \cdot R - 0.63 \cdot B/100 - 0.84 \cdot W/100 \tag{5}$$

where the subscrips in $Q_{6.5pt}$ and $Q_{10.5pt}$ implied sizes of the characters.

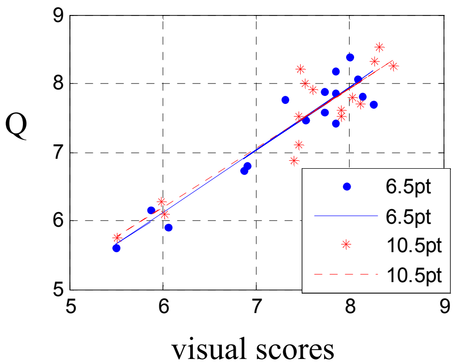


Fig. 3 Relations between the quality factor Q values and the visual scores

When relating the factor values to the evaluation score data, a better linear relation exists between the two, as shown in Fig.3, and correspondence coefficients R^2 were 0.94 and 0.91 respectively.

So, it could be concluded that the PTD could be represented by the factor Q and further linearly relevant to the four attributes as in Eq.3. Secondly, it could be seen from Eq.4 and Eq.5 that the factor Q is always positively relevant to C, and negatively relevant to R, B and W. This is to say that increasing C value could improve the text perceptual definition, whereas only decreasing R, B or W values could the aim be achieved.

In fact, it is well-known that a line with bigger contrast may aid to enhance definition conception, and a smooth and sharp line will appear clear to recognize. So it is very easily understood the conclusions that Q values is positively relevant to C and negatively relevant to R and B.

For a single line, enhancing its width may usually make it easily recognized. But when lots of lines get together, line's widening would increse the possibility of theirs overlap, especisily in case of bigger B values. And human eyesight will decrese as line's gethering. So, it would no doubt decrese the PTD. Maybe just the reason is the cause of results in Eq.4 and Eq.5. So, this indicats that, for the multi-stroke Chines charcter in Fig.2, spaces between strokes had already small enought that only decreaing the stroke width would the PTD be enhanced. Actually, in our other experiment, the factor Q was positively relevant to the stroke width for simple (i.e. a little of strokes) characters [4].

Additional, the Eq.5 denotes that the PTD is also negatively relevant to its stroke width like that in Eq.4, even if its size has enlarged to 10.5 point. But the effect extent of line width on the perceived definition now is somewhat smaller than that in size of 6.5 point, illustrating that relative perception weighting of line width in PTD will fall as spaces between strokes in a character getting bigger.

Conclusions

In this paper, we have made a study on PTD for a multi-stroke Chinese character prints digitally printed, and proposed a model for obtaining its PTD quality factor, which is linearly relevant to character stroke's contrast, raggedness, blurriness and width.

Our results show that, for the experimented multi-stroke Chinese character, the definition quality factor is positively relevant to its stroke contrast, and negatively relevant to stroke raggedness, blurriness, and width, both in cases of two sizes of 6.5 and 10.5 points. So, for multi-stroke Chinese characters, we could increase the first attribute parameter and decrease the later three ones.

Acknowledgements

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