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Barcode Design by Evolutionary Computation

Satoshi Ono Kensuke Morinaga Shigeru Nakayama
Department of Information and Computer Science,
Faculty of Engineering, Kagoshima University
1-21-40, Korimoto, Kagoshima, 890-0065 Japan
{ono, sc104059, shignaka}@ics.kagoshima-u.ac.jp

Abstract

This paper proposes a system for generating 2-dimensional barcode incorporated some illustrations inside of the code without detracting machine-readability and stored information. We formulate the task that finding appropriate position, scale, and angle of an illustration, photo, logo or other image item put in QR code as an optimization problem. By using evolutionary computation algorithm, the proposed system can find positions in which a given image item can be merged without damaging machine-readability and stored information.
keywords: barcode design, QR code, optimization, evolutionary computation, genetic algorithm

1 Introduction

Barcode is used in various purposes such as merchandise control, book collection control in libraries, and so on. QR code[1] , a kind of two-dimensional barcode investigated by Denso Wave, is used as so-called shortcut to get a URL, e-mail address, phone number and so on, in recent Japan. Most of Japanese mobile phones have QR code scanner using equipped cameras. By holding a mobile phone over QR code printed on papers, billboards, or television screens, users therefore can get decoded information and browse Web site, or send e-mail without typing URL or e-mail address on their mobile phones.

Although QR code can involve various information such as URL, e-mail address, short sound, and so on, users cannot know what kind of information is implanted in it (from QR code itself). In addition, QR code is dreary and occupies not a small area in limited, worthy space of papers, billboards, or other media.

QR code has an error correction function which can supplement at most 30% data loss. An illustration therefore can be put inside of QR code. QR code with an illustration is more attractive than a general, boring QR code. In addition, it can let humans know what kind of information is implanted in the code.

But putting an illustration into QR code often damages machine-readability or implanted information. It is difficult to find an appropriate place in order to let the error correction work well and to keep machine-readability. Larger illustration or more images makes this problem more difficult.

This paper proposes a system for generating 2-dimensional barcode incorporated with some illustrations inside of the code without detracting machine-readability and stored information. We formulate the task that finding appropriate position, scale, and angle of an illustration, photo, logo or other image item put in QR code as an optimization problem. By using evolutionary computation algorithm, the proposed system can find positions in which a given image item can be merged without damaging machine-readability and stored information. The proposed system can also incorporate more than one images into a QR code. Experiments have showed that our system can generate QR codes containing 3 illustrations without damaging QR code function and embedded data.

2 Proposed QR-code design system

2.1 Basic idea

The principles of the proposed system for generating 2-dimensional bar code with illustrations are as follows:

1. **Formulating the task of decorating QR codes by placing illustrations in the code as an optimization problems.**

   Deciding the positions of illustrations requires iteration of trial production of the barcode with

[1] QR code is trademarked by Denso Wave, inc.

the illustrations and test for decode practicability. This is because we cannot know the appropriate place where the illustrations should be placed in the barcode in advance. We therefore formulate this task as an optimization problem. The objective function is composed of feasibility of decoding evaluated by QR code decoder, and adequacy of positions and other parameters of the incorporated image based on human-readability.

2. **Using real-coded genetic algorithm to find an appropriate image positions.**

   Genetic algorithm (GA) is well-known metaheuristics for optimization inspired by evolutionary biology. GA can produce better solutions by recombining good "building blocks"[1]. Traditionally, genes are represented in binary, but real values and other encodings are also possible in recent years. Because positions and other parameters providing a barcode with illsutrations should be real numbers instead of sequences of binary variables, the proposed system utilizes real-coded GA[2, 3, 4].

3. **Evaluating solution candidates by plural QR code decoders.**

   Most of recent mobile phones on the market in Japan involve a QR code decoder software developed by the mobile phone manufacturer or other subcontract software developer. Although it is hard to prepare and use the same QR code decoders as mobile phones use, we try to ensure the robustness of generated QR codes by using plural QR code decoders. The more QR code decoders the proposed system uses, the more mobile phones can read the generated codes.

2.2 Chromosome representation

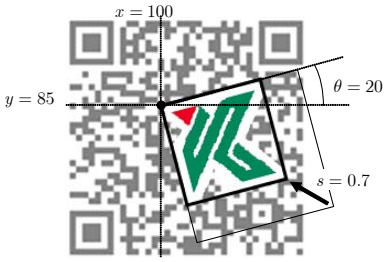
QR code design problem involves continuous variables of which the number is four multiplied by the number of illustrations: x- and y-axis positions x_i, y_i , an inclination θ_i, and a scale s_i for each illustration i. A chromosome, i.e. genotypic representation, consists of the variables coded as integers and real values. Positions and an inclination are coded as integers and scales as real values. The phenotypic representation is formed by placing illustrations along the variables, as shown in Figure 1.

2.3 Process flow

The inputs of the proposed system are a QR code and illustrations. The QR code can be easily generated

$$(x, y, s, \theta) = (100, 85, 0.7, 20)$$

(a) Genotypic representation.



(b) Phenotypic represenatation.

Figure 1: Chromosome representation.

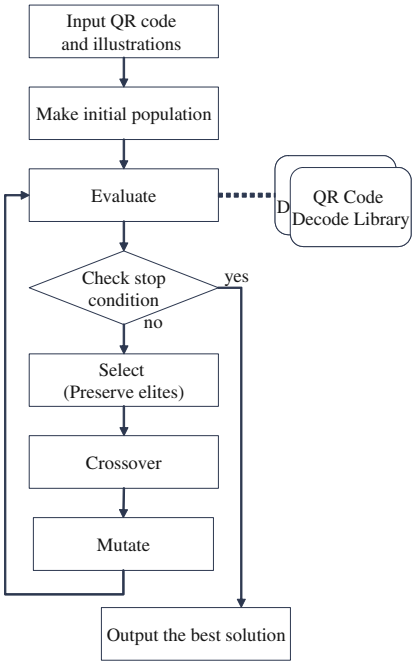


Figure 2: Process flow of the proposed method.

by using open software or services on various web sites.

The proposed system iterates generation of decorated QR codes with illustrations and test of the QR codes by using software decoders. Real-coded GA[2, 3, 4] is adopted to optimize the illustration placement, as shown in Figure 2. The proposed method utilizes blend crossover (BLX-α), a simple crossover operator for real-coded GA proposed by Eshelman[4].

2.4 Evaluation with QR code decoders

The proposed system uses more than one QR code decoders to evaluate individuals, which is a QR code with illustrations inside for the sake of enhancing robustness of the QR code. Fitness $F(x)$ of an individual x is a product of success rate of decoding $P(x)$ and appropriateness of illustrations' positions $Q(x)$.

$$F(x) = P(x) \times Q(x)$$

$P(x)$ indicates how x can be decoded properly and is calculated as follows:

$$P(x) = \frac{\sum_k p_k(x) \times w_k^{(p)}}{\sum_k w_k^{(p)}}$$

$p_k(x)$ is calculated from decode result of a decoder k; $p_k(x) = 1$ if a decoder succeeds in extracting information. In the case that a decoder k does not produce any data except the fact that the decoder failed to decode, $p_k(x) = 0$ when the decoder failed. In the case that a decoder k can present decode error amount, $p_k(x)$ is calculated by subtracting error rate from 1.0.

$Q(x)$ indicates how x places illustrations appropriately in its QR code, and calculated as follows:

$$Q(x) = \prod_l q_l(x)^{w_l^{(q)}}$$

The proposed system uses following four functions to calculate $Q(x)$: how illustrations are overlapped each other ($q_1(x)$), how illustrations are placed appropriately inside of QR code ($q_2(x)$), how large illustrations are magnified ($q_3(x)$), and how illustrations are magnified or reduced with the same scale between illustrations($q_4(x)$).

$w_k^{(p)}$ and $w_l^{(q)}$ are weight parameters.

3 Example outputs

We implemented the proposed system with Psytec QR Code Decode Library[2] and Open Source QR Code Decode Library[3] .

Psytec library outputs information embedded in a given QR code only when the code is decodable, and does not produce any information when the code cannot be decoded. Open Source decode library outputs information embedded in the code even when the library cannot decode the code entirely. Thereby the decode error rate can be calculated by comparing the library's output and embedded information.

[2] http://www.psytec.co.jp/product/03/
[3] http://sourceforge.jp/projects/qrcode

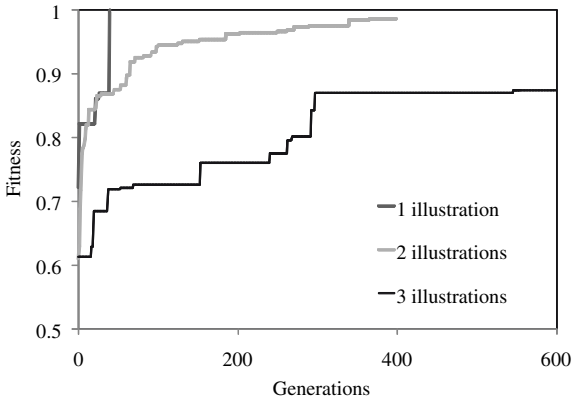


Figure 3: Fitness transitions.

We tried to make QR code with one to three illustrations, and evaluated the generated QR codes with 10 mobile phones on the market. We performed 5 runs for each number of illustrations. The number of individuals, the number of elites, and the generation limit are set to 10, 2, and $200 \times N_i$, respectively, where N_i is the number of illustrations.

Figure 3 shows transitions of average fitness, and Figure 4 shows examples of generated QR codes. When placing one illustration, the proposed system can quickly find solutions whose fitness is 1.0 within 50 generations. As the increase of illustrations, it becomes difficult to find a solution x with $F(x) = 1.0$.

Table 1 shows results of decoding with 10 mobile phones. Overall, most of generated QR codes are well-decoded by the mobile phones. All QR codes with one illustration could be decoded with all mobile phones. The second QR code with two illustrations was hard to be decoded and a mobile phone could not decode it. In addition, two mobile phones could not succeed in decoding the third QR code with three illustrations, as shown in the right of Figure 4 (c). The reason can be deduced that the position detection pattern on the left-bottom corner is partly covered by an illustration, which makes it difficult to recognize precise code area for the mobile phones.

4 Conclusions

Proposed in this paper is a QR code design system by placing illustrations, photographs, logo or so inside of the QR code. The proposed system utilizes real-coded GA to optimize illustration positions, scales,

Table 1: Experimental results.

Number of illustrations	Runs	Fitness	Decode results										Success rate	
			SH703i	D903i	P902i	SH902i	N902iS	W52S	neon	W41T	A5516T	A5512CA		
1	1st	1.00	√	√	√	√	√	√	√	√	√	√	100%	100%
	2nd	1.00	√	√	√	√	√	√	√	√	√	√	100%	
	3rd	1.00	√	√	√	√	√	√	√	√	√	√	100%	
	4th	1.00	√	√	√	√	√	√	√	√	√	√	100%	
	5th	1.00	√	√	√	√	√	√	√	√	√	√	100%	
2	1st	1.00	√	√	√	√	√	√	√	√	√	√	100%	98%
	2nd	0.97	√	√	√	x	√	√	√	√	√	√	90%	
	3rd	1.00	√	√	√	√	√	√	√	√	√	√	100%	
	4th	0.97	√	√	√	√	√	√	√	√	√	√	100%	
	5th	1.00	√	√	√	√	√	√	√	√	√	√	100%	
3	1st	0.96	√	√	√	√	√	√	√	√	√	√	100%	96%
	2nd	0.94	√	√	√	√	√	√	√	√	√	√	100%	
	3rd	0.93	√	√	√	x	√	√	√	√	x	√	80%	
	4th	0.89	√	√	√	√	√	√	√	√	√	√	100%	
	5th	0.87	√	√	√	√	√	√	√	√	√	√	100%	

(a) With one illustration.

(b) With two illustrations.

(c) With three illustrations.

Figure 4: Example outputs

and angles, and software decoders of QR codes to evaluate generated QR codes involving illustrations.

In future, we plan to combine interactive evolutionary computation [5] and multiple solution search method [6], and apply the combined model to the proposed QR code generation system.

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