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OPTIMIZATION OF THE JAKIM HALAL LOGO PLACEMENT ON QR CODE USING ENHANCED GENETIC ALGORITHM

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By

FUAAD BIN ROHANI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

May 2018

Specially dedicated to

My parents, my wife and my children

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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May 2018

Chair : Syamsiah Binti Mashohor, PhD
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A logo placed on Quick Response (QR) code provides additional aesthetic value and visual information to the user. Visual quality of the embedded logo is an important criterion besides success in QR code readability. Unfortunately, most work placed a logo on QR code with low embedded data capacity. Therefore, Jabatan Kemajuan Islam Malaysia (JAKIM) halal premises information is used to represent high data capacity. The thesis proposed a method to place a logo on top of the QR code, embedded with high data capacity, using Genetic Algorithm (GA) search technique to find appropriate size and location so the QR code can be decoded by various QR code decoders. Pad codewords modification technique is used to minimize the error introduced by the logo while three QR code decoders are used to achieve high probability of decode feasibility. A fitness function has been formulated to determine the appropriate size and location of the logo. A total of 3949 samples retrieved from JAKIM public access database was segregated into six groups based on the amount of information that could be embedded in the QR code, wherein 10% of the items from each group were used as samples for data generation. From the experiments, logo size about 69 to 76 pixels which covered about 5.39% to 7.16% of the QR code area can be used for all items in the respective group without decoding failure compared to 2% currently used in JAKIM Halal tag. The module pixel error in the QR code is found to be less than 4.25%. The logo placement system had successfully avoided error correction modules and control patterns, simultaneously, the placement location of the logo is maintained within the QR code area. The proposed work has been compared to GA-based technique, module modification technique and Simulated Annealing technique related to QR code readability, embedded logo visual quality and high embedded data capacity. As a conclusion, the system can successfully find a set of logo size and location on a QR code embedded with high data capacity that does not affect the QR code readability and can be decoded by various decoders with 100% accuracy.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PENGOPTIMUMAN PELETAKAN LOGO HALAL JAKIM DI ATAS KOD QR MENGGUNAKAN ALGORITMA GENETIK DITINGKATKAN

Oleh

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Mei 2018

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Logo yang diletakkan pada kod QR memberikan nilai tambah estetik dan maklumat visual kepada pengguna. Kualiti visual logo yang dibenam di dalam kod QR adalah kriteria yang penting selain kejayaan kebolehbacaan kod QR. Malangnya, kebanyakan kerja hanya meletakkan logo pada kod QR yang mempunyai kapasiti data tertanam yang rendah. Oleh itu, maklumat premis halal Jabatan Kemajuan Islam Malaysia (JAKIM) digunakan untuk mewakili kapasiti data yang tinggi. Tesis ini mencadangkan kaedah untuk meletakkan logo di atas kod QR, yang tertanam dengan data berkapasiti tinggi, menggunakan teknik carian Algoritma Genetik (GA) untuk mencari saiz dan lokasi yang sesuai supaya kod QR dapat dinyahkod oleh pelbagai penyahkod kod QR. Teknik pengubahan ruang pad digunakan untuk mengurangkan ralat yang dijana oleh logo manakala tiga jenis penyahkodan kod QR digunakan untuk mendapatkan kebarangkalian kejayaan nyahkod yang tinggi. Fungsi kesesuaian telah dirumus untuk penentuan saiz dan lokasi peletakan logo yang sesuai. Sejumlah 3949 sampel yang diambil dari pangkalan data awam JAKIM telah diasingkan ke dalam enam kumpulan berdasarkan jumlah maklumat yang boleh dimasukkan ke dalam kod QR, dimana 10% daripada item dari setiap kumpulan digunakan sebagai sampel untuk penjanaan data. Daripada eksperimen, saiz logo sekitar 69 hingga 76 piksel yang meliputi di antara 5.39% hingga 7.16% daripada kawasan kod QR boleh digunakan untuk semua sampel dalam kumpulan masing-masing tanpa kegagalan nyahkod berbanding dengan 2% yang digunakan pada tag Halal JAKIM. Ralat piksel modul di dalam kod QR didapati kurang daripada 4.25%. Sistem peletakan logo ini telah berjaya mengelakkan modul pembetulan ralat dan corak kawalan, pada masa yang sama, lokasi letakan logo dikekalkan di dalam kawasan kod QR. Kerja yang dicadangkan telah dibandingkan dengan teknik berasaskan GA, teknik pengubahsuaian modul dan teknik *Simulated Annealing* berkaitan dengan kebolehbacaan kod QR, kualiti visual logo terbenam dan data terbenam berkapasiti tinggi. Sebagai kesimpulan, sistem yang dicadangkan berjaya

menemui set saiz dan lokasi logo pada kod QR yang tertanam dengan kapasiti data yang tinggi yang tidak menjejaskan kebolehbacaan kod QR dan boleh dinyahkod oleh berbagai jenis penyahkodan dengan ketepatan 100%.

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I certify that a Thesis Examination Committee has met on 18 May 2018 to conduct the final examination of Fuaad bin Rohani on his thesis entitled "Optimization of the Jakim Halal Logo Placement on QR Code Using Enhanced Genetic Algorithm" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This is to confirm that:

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Name of Member of Supervisory Committee: Assoc. Prof. Dr. Abd Rahman Bin Ramli

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

QR	Quick Response
2D	Two-dimensional
JAKIM	Jabatan Kemajuan Islam Malaysia
RFID	Radio-frequency identification
NFC	Near-field communication
SA	Simulated Annealing Optimization
GA	Genetic Algorithm
EC	Error correction
ECC	Error Correction Codewords
DE	Differential Evolution
ABC	Artificial Bee Colony
CSS	Charge Search Systematic
PSO	Particle Swarm Optimization
ES	Evolution Strategies
XOR	Exclusive-OR
RGB	Red, Green, Blue

CHAPTER 1

INTRODUCTION

1.1 Background

Quick Response (QR) code is a two-dimensional (2D) barcode originally utilized by the automobile industry in Japan for their production management system (Denso wave, 2000). Increasing awareness and adoption of the QR code, especially in the marketing field, has increased the trend of smartphone users to scan the QR code (Tiwari, 2016). Currently, the use of QR code ranges from food traceability (Ramundo, Taisch, & Terzi, 2016) to document authentication (Tkachenko et al., 2016).

QR code with company's logo can attract more user to scan it compared to plain QR code (Čović & Šimon, 2016). Unfortunately, embedding logo on QR code introduce error to the QR code modules making it difficult to scan (Wang et al., 2015). The embedded logo is preferred to be as large as possible, but must not degrade the readability of the QR code (Lay et al., 2016). High embedded data capacity can degrade the visual quality of the embedded logo (Y.-H. Lin, Chang, & Wu, 2013) because of the limited modules that can be changed freely.

In recent years, Jabatan Kemajuan Islam Malaysia (JAKIM) has introduced a passive QR code known as JAKIM Halal tag (JAKIM, 2012) placed at JAKIM certified halal premises that can be scanned offline using a QR code decoder. Unfortunately, the QR code symbol only can be scanned by i-nigma (http://www.i-nigma.com) QR code decoder which prevented consumer from using a standard QR code decoder. This limitation may not attract its usage as ease of use and reliability are important to the customers (Abd Rahman et al., 2016).

The JAKIM Halal logo has significant contribution to the confidence level of customers (Rezai, Mohamed, & Shamsudin, 2012) and purchase intention (Aziz & Chok, 2013) when they are about to acquire halal product or service. In Malaysia, JAKIM has been given the task of managing halal certifications, making regulations and monitoring the halal industry for any breach of halal certificates and logo. The JAKIM Halal logo is the easiest way for halal consumers to determine halal compliance of JAKIM halal certified premises. Nevertheless, some customers are less confident in the halal logo due to the failure of the authority to adequately enforce law and take action on the misuse of halal logo (Rezai et al., 2012). Unfortunately, halal logo fraud cases appeared such as use of halal logo other than JAKIM Halal logo (Bernama, 2016a, 2016b) and using an unauthorized JAKIM Halal logo (Mohd Amin,

2016) so that the company involved can make profit by confusing halal consumers.

In preventing of such fraud activity from widespread, JAKIM introduced halal portal (JAKIM, 2011) that can be accessed by the public to verify the status of halal products or services. Meanwhile, to strengthen and simplify the verification process of halal products and services, researchers and industries have developed systems using technology such as Radio Frequency Identification (RFID) (Anir, Nizam, & Masliyana, 2008b, 2008a), Near Field Communication (NFC) (Sawari, Ghazali, & Yap, 2015) and QR code (JAKIM, 2012; Sinar Harian, 2012). QR code also being used in other applications (Husny et al., 2014) such as a watermarking image to authenticate halal logo and certificates (Yahaya, Hassan, & Kahmi, 2012).

As JAKIM Halal logo is an important element for consumers to recognize JAKIM halal certified premises (Abu Bakar, Rosslee, & Saidin, 2014), the inclusion of JAKIM Halal logo on top of the QR code provides a visual meaning that the QR code is from JAKIM. The consumers should not be constraint to use only one brand of QR code decoder so that many consumers can get benefit from the application. This problem motivates this project to find the appropriate placement of logo on QR code embedded with high data capacity that can be decoded by various QR code decoders.

1.2 Problem Statement

Several techniques have been developed to superimpose logo on top of QR code without sacrificing the QR code readability such as searching for appropriate placement areas (Ono, Morinaga, & Nakayama, 2008b; Wakahara & Yamamoto, 2011), modification of QR code redundant modules (Wakahara, Yamamoto, & Ochi, 2010), selection of parity bits modules (Fujita, Kuribayashi, & Morii, 2011) and modification of module color intensity (Garateguy et al., 2014). These techniques have their own advantages regarding logo visual quality. Unfortunately, high data capacity usage of the QR code can degrade the visual quality of the embedded logo (Y.-H. Lin et al., 2013).

Premises' address usually has a long stream of characters and when embedded in a QR code requires high data capacity storage. Therefore, the first question is what is the length of premises' address to be used and how it affects the QR code parameters such as version and size. Long information required higher QR code version which makes the size larger compared to shorter information. Therefore, as each premise has different information, the generated QR code is unique to each premise. In order to simulate high data capacity, premises' address is downloaded from JAKIM public database (http://www.halal.gov.my/ehalal) and analyzed to find the distribution of the information length. JAKIM Halal tag is also investigated to find other parameters such as error correction (EC) level and QR code version used.
Placing a logo on top of the QR code introduces noise that prevents the QR

code from being decoded correctly by the QR code decoders available in the market. Y.-H. Lin et al. (2013) used Simulated Annealing Optimization (SA) to find optimal codewords that can minimize the visual distortion of the embedded logo. The technique also required the QR code version number to be increased in order to create more redundant codewords as used by Wakahara et al. (2010) and Fujita et al. (2011). Unfortunately, the logo distortion gets worst when 20% of the QR code data are occupied. Ono et al. (2008b) has formulated a Genetic Algorithm (GA) fitness function to search for appropriate logo placement on QR code that can be decoded successfully by various QR code decoders. This technique uses highest QR code EC level to compensate with the error introduced when a logo is placed on the QR code. Even though data capacity does not affect the logo appearance, there are possibilities of decoding failure by one of QR code decoder used.

The next question is how can the QR code with a logo on top of it can be designed in such a way that various QR code decoders can be used to scan the QR code. As data capacity does not affect the logo visual distortion for the GA technique, this technique can be improved by reformulate the fitness function so that various QR code decoders able to decode the resultant QR code. There are a lot of QR code decoders in the market and each of them have their own advantages and disadvantages. Some decoders have the ability to decode the QR code whenever certain requirement for QR code detection is missing but other decoders may not have the same capability. Therefore, it is essential for important pattern to be retained so that various QR code decoders can be used to scan the QR code with logo on it.

The last question is the possibility of the resultant sample placement candidate to be used by other premises information with different length. The sampling resultant candidate needs to be evaluated against all downloaded premises data to determine the readability of the QR code. A comparison with current implementation needs to be done related to logo size, QR code readability and embedded data capacity.

1.3 Research Aim

This thesis proposed to find appropriate placement of moderate logo size on top of QR code embedded with high data capacity that can be decoded by various QR code decoders.

1.4 Research Objectives

The objectives identified are as follow:

1. To determine the QR code version which is suitable for high data capacity with logo placement.

2. To design an optimal placement of logo using GA on QR code

considering readability, data capacity and visual quality.

3. To evaluate the GA-based logo placement method on QR code with various logos and compare with other logo placement methods.

1.5 Scope of the Study

The embedded information used in the experiments was obtained from JAKIM Halal directory (JAKIM, 2007) on 30 Jan 2014 to 9 Feb 2014 to simulate high data capacity. The data has been formatted to follow the format of JAKIM Halal tag as close as possible.

Mode optimization is not done in generating the QR code due to the limitation of the encoder capability. EC level M is used, same as JAKIM Halal tag. Module size of three pixels is used due to the decoding capability of ZBar and qrcode decoder. Three decoders are used to simulate various decoders.

1.6 Contribution of Thesis

In this thesis, GA-based logo placement technique is improved by reformulate the GA fitness function. The probability of decoding success depends on decoding result of the three QR code decoders. All three QR code decoders must be able to decode the QR code so that the logo placement location can be calculated. Pad codewords, error correction codewords (ECC) and control patterns calculation are added to the logo placement quality function.

1.7 Outline of Thesis

Chapter Two starts with a brief introduction of the QR code standard followed by requirements of logo placement on QR code. QR code with illustration is introduced, followed by optimization techniques used to place logo on QR code. Next, GA parameters and performance metrics regarding logo placement on QR code are given.

Chapter Three presents the methodology and steps involved in implementing the proposed idea. High data capacity dataset distribution is presented, followed by identification of QR code version suitable for pad codewords modification technique. Afterward GA-based QR code generator design is explained, including chromosome representation, fitness function formulation and parameters setting. A method to evaluate GA-based QR code generator to produce placement candidate is described, followed by evaluating the solution to the whole premises dataset. Lastly, method to benchmark the proposed work with current implementation is depicted.

Chapter Four discusses the experimental results and discussion on finding

appropriate placement of logo on top of QR code embedded with premises information. The chapter starts by discussing the selection of appropriate QR code version to be used for pad modification technique followed by parameter tuning and evaluation of the GA-based QR code generator on the premises dataset. Lastly, comparison of related work with the proposed work is considered.

Chapter Five presents the conclusion, limitation of the proposed work and possible future enhancements and usability.

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