Graphic Code: a New Machine Readable Approach

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***Abstract*—Machine Readable Codes have been used for several purposes. Approaches like UPC [1] and QR Code [2] can be seen everywhere. Recently, it has emerged a new MRC [3], [4] able to combine the communication power of classical methods to a meaningful improvement on aesthetics and data capacity. This method is named Graphic Code[1]. Although it has been used in previous researches, this name was firstly used publicly at Security Document World Conference and Exhibition, 2018.**

Graphic Code has two major advantages over classical MRCs: aesthetics and larger coding capacity. It opens new possibilities for several purposes. It can be used for identification, tracking (using a specific border), and transferring of content to the application. In this paper, we will present how graphic code can be used for industry applications, emphasizing its uses on Augmented Reality (AR). In the first context, it is already being used for creating labels and validation stamps. And in the second context, it can be used as a marker (identification and tracking) and to code parameters for an AR application such as large texts, meshes of a 3D model, an image, a drawing, or other complex controls.

***Index Terms*—Machine Readable Code, Graphic Code, Validation Stamps and Labels, AR Markers, Large Scale Information Coding, Aesthetic Coding**

I. Introduction

Over the decades, Machine Readable Codes (MRC) got a huge importance because its ability to communicate a textual information through an image. These patterns can be used to identify products, mobile tagging, product traceability, inventory control, ticketing, etc. The first popular MRC was the 1D barcode, such as UPC [1]. It is very useful to code short messages and it is quickly decoded. Hence, it is internationally used for tagging almost all kind of products. Later, it has appeared the 2D barcodes, such as PDF417 [5], MaxiCode [6], DataMatrix [7] and QR Code [2]. They are able to code more information than 1D barcodes. However, they do not have a good appearance (they seem a random displacement of black and white pixels).

For appearance improvement, it has emerged some techniques [8]–[12] that embeds a picture in the code, whilst it keeps decoding capability. Along this paper, we will refer to these techniques as *Picture-Embedded QR Codes* (PEQRC). In these methods, the coded information uses only very few pixels of the image (what reduces the maximum amount of encoded data). On the other hand, our method uses all pixels for aesthetics and coding what guarantees aesthetics while increases the amount of coded data.

Rekimoto and Ayatsuka [13] presented an approach for creation of tags used for AR. Moreover, they presented several applications of this tags in AR applications, such as Physically embedded links to the digital information, Indoor navigation systems, Annotating the real world by using 3D information, Direct manipulation devices for physical environments, ID transmission in TV programs and Object recognition and registration in ubiquitous computing environments. Furthermore, Kan et. al. [14] introduced an overview about the use of QR Codes for Augmented Reality Applications.

Analogously, we can also use a graphic code for all these tasks. Fig. 1 illustrates the use of a graphic code in AR. The marker in the left contains the identification and position of all elements of a 3D landscape. When the AR application identifies the marker and decode the scene information, the landscape is reconstructed and displayed.

It is noteworthy to say that besides usual application of markers in AR system, graphic code introduces a coding technique able to code much more information than usual machine readable codes. It opens new possibilities for AR and other industry applications.

Graphic Code is a new steganography technique that combines the image visual appeal with the communication power of words. We will present how to create this MRC, with good aesthetic, very large coding capacity, and high-speed scanning. In Section II, we will briefly introduce the coding approach. Next, we will present the novelties of this method. Finally, we will introduce some applications of this technique on industry (creation of labels and validation stamps using graphic code for tagging).

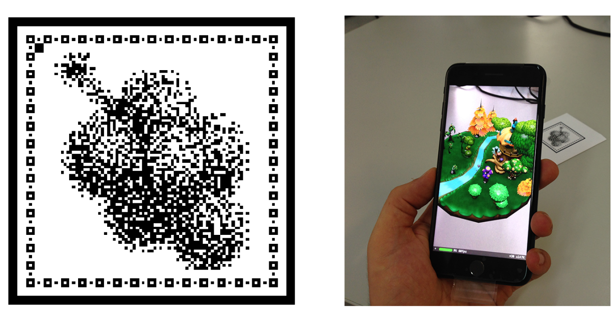

Fig. 1. Example of a graphic code as a marker in an AR application.

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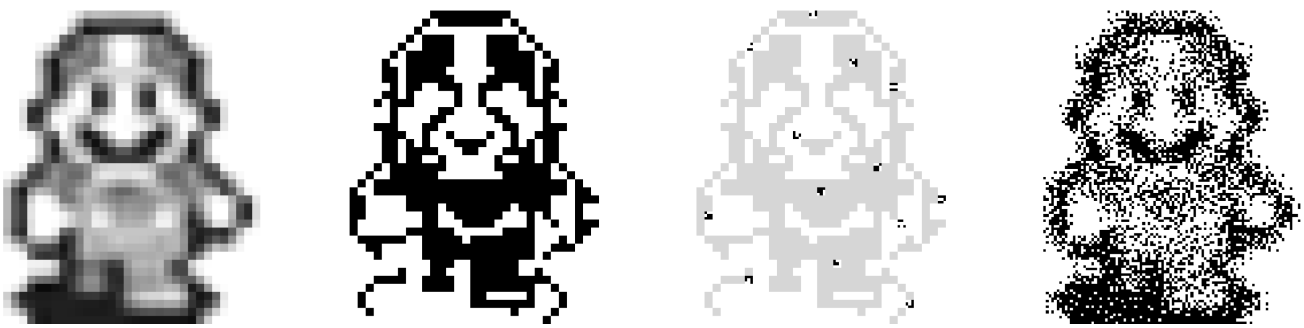
		Graphic Code	PEQRC	QR Code	PDF417	DataMatrix	MaxiCode
Developer		Ours	Many developers	DENSO Wave	Symbol Technologies	RVSI Acuity CiMatrix	UPS
Type		Graphic and PE	PE Matrix	Matrix	Stacked barcode	Matrix	Matrix
Data Capacity	Numeric	15288	7089	7089	2710	3116	138
	Alphanumeric	15288	4296	4296	1850	2355	93
	Binary	7644	2953	2953	118	1556	-
Main features		Enhanced Aesthetic, very large capacity, medium size, high-speed scanning	Aesthetic, large capacity, medium size, high-speed scanning	Large capacity, small size, high-speed scanning	Medium capacity, small size	Medium capacity, small size	High-speed scanning, small size

Fig. 2. Comparison between the graphic code and other machine readable methods.



(a) Base Image (b) Candidates (c) Chosen cells (d) Graphic Code

Fig. 3. The coding pipeline starts from the base image (a). Next, it defines the candidate pixels according to the quanta used in the dictionary (black pixels in (b)), then it places the respective pattern of each message symbol (c) and it finishes the encoding by replacing the remaining cells.

II. Graphic Code

Cruz et. al. [3], [4] introduced a new Machine Readable Coding (MRC) named Graphic Code. This method creates an image by an appropriate organization of **cells**: sets of pixels with a specific format (typically 3×3). Some cell patterns are related to symbols used for coding (the association between a pattern and a symbol is named **dictionary**). In a cell, all pixels are simultaneously used for aesthetic and coding. It allows the creation of aesthetic codes (like those generated by PEQRC) and allows each cell to code a symbol (instead of using a set of cells to encode a symbol, like it is performed by PEQRC). Considering all pixels as a single pattern allows the graphic code to encode more information than classical MRCs.

The encoding and decoding processes are symmetrical and both receive as input the same dictionary and grid of pixels (defining the code resolution, and the area of the image it will be used). Moreover, the encoding receives message to be encoded, and when necessary, a base image. Furthermore, the decoding also receives the graphic code itself, and returns the recovered message.

The encoding process is based in a quantum system (regular division of the grayscale range in 10 classes). Given a base image (Fig. 3a), each grid cell (arrangements of 3×3 pixels) will be encoded with a pattern which the quantum relates to the color of the respective pixel in the base image. We use the cells of the quanta Q3, Q4, Q5 and Q6 to be possibly associated to the symbols of the message, because only they have enough quantities of different patterns able to be used with alphanumeric dictionary (containing 75 characters).

Thus, the encoding starts by identifying the cells of these quanta. We call them **candidates**. They are shown in Fig. 3b as black pixels. Then, we choose one cell per character of the message and replace them by the respective pattern in the dictionary. The remaining cells (both unselected candidates and non-candidates) are replaced using non-dictionary patterns (the pattern is chosen according to the quantum of the respective pixel in base image). Fig. 3c highlights the candidate cells used for the message symbols, and Fig. 3d shows the final graphic code, with all replacements.

The decoding process is the inverse. In the same order used in encoding, we go through the grid searching for patterns that are in the dictionary. Whenever one of them is found, the respective symbol is concatenated to the message that is being retrieved.

(a) (b) (c) (d)

Fig. 4. Validation stamp of Portuguese tobacco: (a) stamp, (b) code composition, (c) graphic code using blue and white pixels and (d) using icons.

(a) (b)

Fig. 5. Examples of graphic code applications: (a) in a label of a bottle and (b) on two validation stamps.

MRCs are widely used because its ability to be decoded from a photo even when the code has printing problems, when it is dirty, and over different lightning conditions. An entire discussion about the graphic code reconstruction from an image is out of the scope of this paper. But briefly, we use a knowledge of a pre-defined patterns around the code (like the border around the code in Fig. 1 and 5) or the entire layout containing regions that are not customized according to the coding (for example the layout of validation stamps in Fig. 4 and 5). By using this previous knowledge, we can rectify the code area, perform a proper sampling (to reconstruct the code) and apply the decoding algorithm. We also use a data redundancy to improve the reconstruction robustness [15] and check digit to validate the decoding [16].

III. Coding Advances

Current MRCs are widely used for encoding products identification numbers (product tagging), URL (mobile tagging), business cards, and small texts for general purposes. In all these cases, the encoded message is not too big. The size of the encoded message is limited because when the code is small, its reconstruction is more efficient (and classical MRC did not evolve for much bigger models). In the opposite direction of classical MRCs, graphic codes need more resolution for aesthetic improvement. Thus, since its conception, larger coding is an important requirement.

Our method is inspired by dithering. It performs a pixel spreading similar to most of PEQRC. However, we choose the cell pattern (specific choice of each pixel color) according to the respective cell quantum (like dithering) and the pattern is according to the encoding (in the cells used to code a message character, the pattern comes from the dictionary, and otherwise, the patterns do not belong to the dictionary). So, all pixels are used at the same time for coding and aesthetic purposes. Besides aesthetic, our codes can afford a large amount of encoded data, what is an advance in state of the art of MRC systems while it keeps the decoding performance.

Fig. 2 compares graphic code to other five famous MRC, emphasizing that our method can code much more data (these quantities were calculated for codes of the same size of the largest PEQRC). This table is an extension of the one presented by Denso Wave [2].

Patrão et. al. [3] introduced the creation of a new Augmented Reality markers using graphic codes. Graphic code allows the creation of applications that handle with larger models (like meshes, curves and images) that are unusual for traditional MRC. Furthermore, it can be used for data transferring for augmented reality applications. The increasing of data coding allows the use of graphic codes in contexts that are not usual for MRCs nowadays.

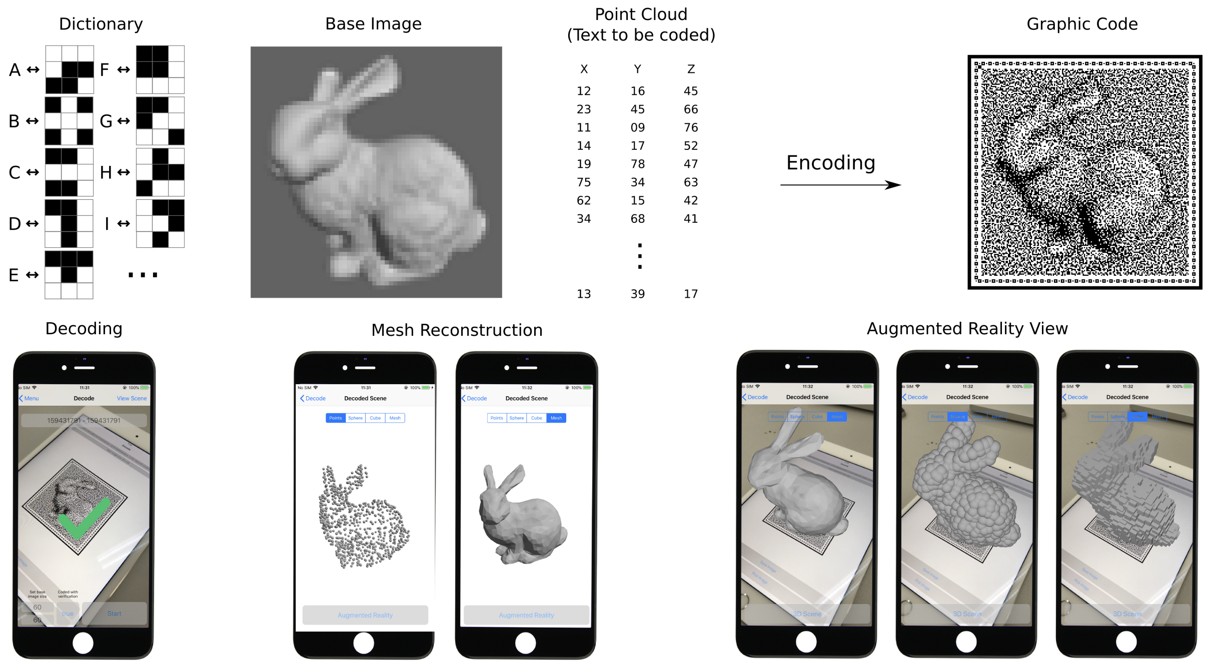


Fig. 6. The pipeline to use a graphic code as marker that transfers a point cloud to an AR application

IV. Applications

The power of MRCs is due to its ubiquity: they can be quickly identified and decoded from devices using customer cameras. Hence, they can be used for several purposes, such as products identification, mobile tagging, product traceability, inventory control, ticketing, business cards, etc. Graphic code has been tested in several conditions of lightning, printing and paper dirty and it presented good reconstruction/decoding results being as robust as classical MRCs. Fig. 5a illustrates the use of a graphic code in a label of a bottle of a wine (it is an illustrative image, and it does not represent a real product). It can be used for product tagging.

Graphic code has been used in a strict standard (pre-established dictionary and code resolution) or embed in a specific layout (the code occupying a specific part of a model) like in the validation stamps illustrated in Fig. 4 and 5. The first case, is the validation stamp used in Portuguese tobacco in the year of 2018 (graphic code is embedded in the stamp). The second case (Fig. 5b) shows two types of wine validation stamps (using a standardized code).

Furthermore, Fig. 4 shows a stamp containing three graphic codes: two black and white and another a green and white. However, the biggest changing in this example is the replacement of two colors pixels coding by cells using icons (Fig. 4d). A full description of this method is out of the scope of this paper, but it enhances even more the code aesthetics.

Graphic code can be also used for creation of augmented reality markers used for identification and tracking, as well as in classical MRCs [13], [14]. Furthermore, due to its large coding capacity, it can be used for transferring other types of models like meshes (Fig. 6), large texts, images, drawings, etc.

It was presented a new MRC that can be used for several purposes, from product identification and traceability to augmented reality applications. It is already being used in the creation of labels, validation stamps and security documents. Finally, the two graphic code advantages in relation to the classical MRCs (aesthetics and larger coding capacity) has opened new possibilities for industry applications.

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