

## Method for creating an aesthetic QR code

The invention relates to a method for generating a 2D barcode embedded in an image. The description is given using QR codes as an example.

QR codes and other two-dimensional or 2D barcodes have become established in private and professional communication as a means of quickly accessing digital content via visual means. The high volume and high aesthetic similarity of QR codes mean that they are increasingly perceived as uninteresting or unimportant. This gives rise to the search for alternative representations that retain their technical functionality.

Many of these processes have the problem that the resulting aesthetic QR codes can no longer be reliably read with common mobile phone cameras and apps.

The publication S. -S. Lin, M.-C. Hu, C.-H. Lee and T.-Y. Lee, “Efficient QR Code Beautification With High Quality Visual Content,” in IEEE Transactions on Multimedia, Vol. 17, No. 9, pp. 1515-1524 (September 2015, doi: 10.1109/TMM.2015.2437711 ) and the further publication Y. -H. Lin, Y.-P. Chang and J.-L. Wu, “Appearance-Based QR Code Beautifier,” in IEEE Transactions on Multimedia, Vol. 15, No. 8, pp. 2198-2207 (December 2013, doi: 10.1109/TMM.2013.2271745) disclose a method in which a QR code (of a certain version, i.e., size) always consists of the same number of cells, even if the actual information to be encoded uses significantly fewer bits. A distinction is made between *message bits*, which actually encode information, and *padding bits*, i.e., cells that do not encode any information at all. In addition, there are further regions, so-called *parity bits*, which are required for error correction, as well as functional cells that help the camera recognize the positioning of the code. In the method, the bit sequence is modified so that all padding bits are located in the center of the image. Since the padding bits do not encode any relevant information, they can be covered by the image. The entire process is a multi-stage procedure that uses optimization methods to maximize the space available for the image, including by exploiting error tolerance. A disadvantage is that the actual amount of information that can be stored in such a QR code is significantly less than with conventional QR codes. In other words, the area available for the image is inversely proportional to the amount of stored information. A further limitation of this process is that for

larger QR code versions, which also have functional areas in the center, these areas are necessarily located in the center of the image. In the publication H. Su et al., "ArtCoder: An End-to-end Method for Generating Scanning-robust Stylized QR Codes," 2021 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), Nashville, TN, USA, 2021, pp.2277-2286 (doi: 10.1109/CVPR46437.2021.00231) describes a method based on the technique of neural style transfer. In this AI method, a content image is rendered in the style of another style image. This style transfer technique is supplemented in this literature by the additional integration of a QR code. The result is a QR code that reproduces the content image in the style of the style image, as is common with neural style transfer, and also functions as a scannable QR code. One limitation of using a neural network is that the result is difficult for the user to control. The same publication also discusses methods for ensuring scannability; what is missing, however, is the consideration of distortions that are not part of the QR code itself, but arise only through its use in real environments, such as dirt or damage. For this reason, this teaching is inadequate for real-world testing.

KR 101260499 B1 teaches a QR code comprising multiple layers, with the actual QR code layer being formed by overlaying the black cells of a classic QR code and a filter that determines both the color and form of the non-transparent parts of the QR code. However, this method loses the information from the white-coded cells, leading to higher error rates and significantly stricter restrictions in the selection of the background image. This method is no longer considered suitable, especially if the background image contains dark areas, since the originally white cells would then be interpreted as black by a camera.

CN 110766117 A teaches a method consisting of many steps: converting a background image into a grayscale image; determining contour lines from the grayscale image; merging the contour lines with the background image and a QR code; and restoring the colors of the original image in a reduced color spectrum. This is a fundamentally different approach than the present invention.

US 12020114 B1 describes a method for scannability testing. It aims to test a QR code in various background environments. From a technical perspective, this appears unsuitable for making an actual prediction about scannability, as required within the scope of the invention, since only elements outside the QR code are taken into account, not the numerous forms of distortion that can occur on and in the QR code itself.

US9805296B2 and AU2023201145B1 teach methods for generating aesthetic QR codes, whereby parts of the QR code cells are made transparent. Unfortunately, these consist of only two layers each, and thus the QR code information must be placed over the entire image, which is distracting because it potentially distorts or even obscures important parts of the base image.

The invention aims to create a method that satisfactorily combines a large number of different base images with a QR code. The method should be fast, reliable, highly scannable, and highly automated. It should also be reliable enough to produce an aesthetic QR code that can be used reliably in practice.

The method according to the invention achieves this by comprising the following steps:

- (a) Selection of a base image, dividing the base image into modules according to the QR grid,
- (b) Selection of an initial code with a predetermined coding of modules in bits with the bit values black or white as the second image layer, wherein the modules of the initial code are each marked as primary or non-primary,
- (c) Storing each module of the initial code on the corresponding module of the base image by inserting the respective bit value into the module, whereby

in the case of a primary module of the initial code, this module is completely filled with the bit value if the color or gray values of the graphic content of the module of the base image differ substantially from the bit value of the associated primary module, and

in the case of a non-primary module, a portion of the module of the base image is filled with the bit value,

thereby creating an interim image with modules,

- (d.1) Selection of a second base image,
- (d.2) Generation of a third image layer by assigning transparency values to the modules of the second base image, whereby modules of higher aesthetic importance are assigned a lower transparency value,

(e) Generation of the embedded code by overlaying the modules of the third image layer onto the modules of the interim image according to their transparency value. An embodiment of the method results from the fact that the second base image in step (d.1) is identical or substantially identical to the first base image.

One embodiment of the method results from the fact that the sub-area of the module of the base image in step (c) is a central area of the module, whose area is, in particular, between approximately 30% and 70% of the area of the entire module, and whose perimeter is, in particular, square, square with rounded corners, circular, or heart-shaped. This provides further parameters for adapting the base image or the code in such a way that a usable aesthetic code is created. In addition, special shapes that are initially invisible to the human eye can refer to a particular manufacturing process and thus to a particular manufacturer.

One embodiment of the method results from selecting regions of higher importance in the base image after step (b.1), and shifting modules of the initial code from the corresponding region therein to other regions of the initial code while preserving the encoded information. This also provides additional parameters for adapting the base image or the code in such a way that a usable aesthetic code is created.

One embodiment of the method results from the base image comprising visible written and/or pictorial information. This expands the application and security spectrum of an aesthetic code.

An embodiment of the method results from the fact that the step is further provided: (f) converting the embedded code by one or more graphical distortions using parameters A,

(g) Testing the scannability of the distorted embedded code,

(h) Either after determining scannability, confirming the embedded code as suitable, or otherwise one or more times:

Generating another base image with changed graphic parameters and/or generating another third image layer with a different assignment of transparency values, as well as

Generating further embedded code,

Repeating the scannability test until scannability is determined and further embedded code is confirmed.

These steps ensure that the released code works. An embodiment of the method is provided by:

(f') converting the embedded code into a population of test images by one or more graphic distortions using the parameters A, wherein the parameters (A) differ from one another in the test images,

(g') Testing the scannability of all test images of the population and determining a recognition statistic,

(h') Either after reaching a predetermined success value, confirming the embedded code as suitable, or otherwise one or more times:

Generation of a further third image layer with a different assignment of transparency values, and

Generation of another embedded code,

Repeat the scannability test of the additional population until the specified success value is reached and the additional embedded code is confirmed.

These steps better ensure that the published code works.

One embodiment of the method results from the parameters A comprising one or more from the list:

- a. one or more perspective distortions,
- b. curvature of the entire embedded code or parts thereof,
- c. artificial reflection of light,
- d. artificial partial or complete shading,
- e. soiling and/or damage,
- f. covering or tearing,
- g. resolution and color spectrum of a physical printer,
- h. simulation of graphic alienation by printing or screen display of the embedded code.

These and the following steps ensure that the published code works.

An embodiment of the method results from the fact that, before step (b), the initial code is modified using predetermined parameters B, which in particular comprise one or more from the list:

- a. Modification of the format version of the code,
- b. Modification of the form of the modules of the code,
- c. Modification of the mask of the code.

One embodiment of the method results from the fact that, before step (a), the base image is modified using predetermined parameters C, which in particular comprise one or more from the list:

- a. Modification of the image section,
- b. Modification of the resolution of the base image,
- c. Modification of the brightness and/or contrast of the base image.

An embodiment of the method results from the fact that after step (e) the embedded code is either confirmed or rejected by an instance using an evaluation, wherein after the rejection steps d.1 and d.2 are repeated one or more times using parameters B and C until the further embedded code is confirmed by applying the evaluation.

An embodiment of the method results from the fact that the instance is a person or a AI module, wherein the AI module is trained on the basis of a data set of evaluations performed by people.

One embodiment of the method provides for the creation of a sequence of embedded codes from a sequence of base images and a common initial code, wherein the sequence of embedded codes is combined into a movie file. This makes it possible to extend the method proposed here to include movies as base images/base graphics.

The invention is explained using exemplary embodiments and the drawings, in which **Fig. 1a** shows an aesthetic QR code, **Fig. 1b** shows an aesthetic QR code in black and white, **Fig. 2** shows a schematic section of an aesthetic QR code, **Fig. 3a** shows the structure of an aesthetic QR code, **Fig. 3b**, **Fig. 3c** and **Fig. 3d** show the structure of an aesthetic QR code, **Fig. 4a to Fig. 4j** show simulated distortions of an aesthetic QR code, **Fig. 4k to Fig. 4t** show simulated distortions of an aesthetic QR code in black and white, **Fig. 5 to Fig. 8** show block diagrams of

aspects of the method for generating an aesthetic QR code, **Fig. 9a** and **Fig. 9b** each show an aesthetic QR code with round and heart-shaped coding areas, **Fig. 9c** and **Fig. 9d** each show an aesthetic QR code in black and white.

The proposed method essentially involves generating an aesthetic two-dimensional barcode, such as a Data Matrix code (DM code) or a QR code, by building up layers. This method is applicable to all 2D barcodes. The following describes it using QR codes as an example.

**Fig. 1a** shows an example of an aesthetic QR code, which contains both the functionality of a conventional QR code and a graphic representation in color,

**Fig. 1 b** illustrates the same in black/white and grayscale.

According to **Fig. 2**, an aesthetic QR code is constructed from modules, or cells 11, where each cell contains or can contain a bit value 12 of the QR code and/or an image portion 13. It is now necessary to determine how each cell 11 is to be configured for a given QR code and a specific graphic representation as the base image.

The proposed method forms three layers according to **Fig. 3a, 3b, 3c** and **3d**, which together lead to the desired aesthetic QR code:

1. Bottom layer: Background - contains the image to be displayed.
2. Middle layer: QR code information (in usual black and white coding).
3. Top layer: Foreground – partially transparent image information that repeats parts of the image in the bottom layer and thus partially covers the QR code. The image in the top layer can be the same as the one in the bottom layer (examples: **Fig. 3a, Fig. 3b**) or consist of a different image (examples: **Fig. 3c, Fig. 3d**).

The bottom layer comprises an (initial) base image, which can be chosen almost arbitrarily.

However, during the generation of the aesthetic QR code, it is possible that the base image will be adapted using graphical means. It is also possible that certain graphically extreme representations may be difficult or even impossible to combine with a QR code due to incompatibility with the QR code information.

The QR code information in the middle layer is designed so that not every cell 11 is completely encoded in black and white, but rather a portion (**Fig. 2**) remains transparent, thus allowing the

underlying image layer to remain visible. For individual areas of the QR code that are particularly important for readability, cells 11 are completely filled.

The third layer conceals the QR code information in parts of the image, and in other parts, the black and white coding is transformed into differently colored light and dark elements using partially transparent image elements. Thanks to the error tolerance built into the QR code standard, the QR code can still be read correctly even if parts of the pixels encoding the QR code information are no longer legible. In a first embodiment, the third layer repeats the image information from the lowest layer 1:1 in as many areas as possible, thus making it possible to display parts of the image entirely without any distracting QR pixels.

The third step of overlaying is performed using conventional graphic overlay algorithms. This means that a field with a given graphic content is overlaid with a second graphic content at a ratio of 0% to 100%. Various approaches to this overlay (pixel-by-pixel, area-by-area, color change of areas or pixels) are possible and can either be selected or implemented predefined by the graphics program.

The base image is first divided into a grid. The grid corresponds to the grid format that corresponds to the QR code to be used. The subdivision of the base image results in a matrix of, in most cases, square cells 11, where each cell 11 is then to be combined with the corresponding module of the QR code. One partial area remains unchanged and shows the image part 13 from cell 11 of the base image. The remainder receives the bit value 12 of the corresponding module of the QR code. The area share, the area shape, and the exact position of the bit value 12 can be varied. The area share can be between 30% and 70% of the area of the entire cell 11; it can also be expressed graphically in the number of pixels and can be as small as just one pixel. The shape can be round, angular, square with sharp or rounded corners, or even heart-shaped. The position is, for example, centrally in a cell 11 or, as shown in Fig. 2, in a corner. **Fig. 9a** shows an aesthetic QR code with partially round bits, and Fig. 9b shows one with partially heart-shaped bits. **Fig. 9c** and **Fig. 9d** show analogs in black and white.

In contrast to the state of the art, the QR code layer can be completely partially transparent except for the functional areas, thus displaying the aesthetic background image across the entire surface of the QR code. The border with the "classic" QR code pattern, which is sometimes mandatory in state-of-the-art processes, is omitted here.

The aesthetic QR code, initially constructed in three layers, is first subjected to quality assurance, i.e. a test for scannability, i.e. readability of the coded information, before it is issued as the final result of the process. This is achieved by simulating realistic scannability impairments in real-world environments, thus determining an average scannability rate in real-world environments. By iterating over the QR code generation, this method allows the creation of aesthetic QR codes that meet definable minimum requirements for technical scannability.

Specifically, the process consists of the following steps, demonstrated using the example of **Fig. 4a** to **Fig. 4j**. Under real-world conditions, a QR code may appear distorted and/or visually impaired permanently or only at the moment of scanning due to:

Fig. 4a: perspective distortions,

Fig. 4b: Curvature of the entire QR code or parts of it,

Fig. 4c: (artificial) reflections, e.g. for codes printed on or presented behind reflective material,

Fig. 4d: (artificial) shadow,

Fig. 4e: Soiling/damage of the QR code,

Fig. 4f: Covering (here e.g. by a fingertip)/ tear/ damage to parts of the code.

Changes can also occur due to the resolution and color spectrum of a physical printer, as well as the characteristics of the print or display medium, which can be simulated. Contamination can be simulated by adjusting the so-called seed value:

Fig. 4g: Contamination with a seed value of 4023.

As shown in Fig. 4h and Fig. 4i, combinations and overlaps of distortion effects can also occur. These are also simulated during quality assurance. According to Fig. 4j, different print results can occur depending on any intermediate image processing using an RGB or CMYK color profile, which can also lead to altered scannability and is therefore tested.

**Fig. 4k** to **Fig. 4t** show analogs in black and white.

In contrast to state-of-the-art methods, scannability testing follows a "top-down" approach, as a finished QR code is tested and subjected to many realistic distortions. In the state of the art, however, a "bottom-up" approach is taught, where, starting from an understanding of how

scanning algorithms work, When creating the QR code, we try to avoid elements that could impair readability. However, this severely limits the freedom to choose base images and adapt them.

Each distortion can be determined by several parameters (e.g., angle of perspective distortion, shape, intensity, and gradient of a shadow). An initially generated aesthetic QR code therefore serves as the starting point for a series of tests. The quality assurance process then includes the following steps:

Creation of a test series using different combinations of distortions, with:

- a. specifying the number of test images;
- b. each test image is created by applying randomly selected distortions with randomly selected parameters to the original aesthetic QR code (because many of the parameters are numeric, there are virtually infinite possibilities for test images for each aesthetic QR code);
- c. the random selection can also be controlled depending on requirements (e.g., increased selection of a specific printing medium on which the code should primarily be printed).

In a second step, statistics on the scannability of the test series are determined:

- d. each image of the test series is scanned using standard algorithms for QR code scanning,
- e. the scan result is recorded for each image of the test series with the two possible values 0/1 for success/failure,
- f. determination of success statistics (e.g. average of the individual scan results).

If the statistics shown in **Fig. 5** reach a predetermined minimum value ("minimum requirement met"), the initially generated aesthetic QR code is considered usable and is issued as a "finished QR code," or final aesthetic QR code. Otherwise, the process for generating a three-layer aesthetic QR code is repeated, with the image processing steps being performed for each of the three layers under modified parameters B and C.

In **Fig. 5**, "QR code generation" represents a suitable method for creating an aesthetic QR code from three layers, which can create a new aesthetic QR code based on image and QR code

information, thus making changes to a given aesthetic QR code is possible. The data in an aesthetic QR code must be technically separated into image information and QR code information, which allows for separate revision of a design. "Determining scannability" is done using the process described above.

The repeated creation of an aesthetic QR code with different parameters can be performed by a single person. Alternatively, it can be automated by an AI-based artificial intelligence that learns the scannability. In addition, AI can also learn user preferences, which can be objectively determined, for example, through A/B testing.

**Fig. 6** shows a machine or program logic for generating aesthetic QR codes (images with embedded QR codes). Hyperparameters are used here that affect non-graphical properties of image files and QR codes, i.e., not brightness, color values, shape of cells and areas, etc. These include, for example, selecting from a variety of QR code versions as a template, file type, and the like.

The method from **Fig. 6** requires as input 102 data to be integrated into the QR code as well as the input 104 of a base image. Context data, such as descriptive keywords (names of individual people, companies, or events for which a specific code was created, or the like), can also be entered as optional input 122. From these inputs and hyperparameters 106 and 112, the QR generator generates in step 108 a QR code 114 optimized for embedding in the image. A first image generator 110 generates 116 a variant of the base image optimized for the integration of the QR code. From these inputs, as well as further hyperparameters and optional context 122 provided as input parameters, the generator 120 generates an image with an integrated QR code, i.e., a preliminary aesthetic QR code (so-called QR image combination 124). A discriminator 126 checks this image for criteria such as the correct readability of the QR code and the learned human preferences. These preferences are learned by the discriminator 126 providing one or more example images 130 to the human evaluator 132. The example images 130 are evaluated by the human evaluator 132 using an evaluation input 128. Based on this evaluation data and the evaluation of the technical quality criteria, the discriminator 128 again adjusts the hyperparameters 106, 112, and 118 of the generators 108, 110, and 120. This loop repeats until the human evaluator 132 signals the end of the process via a special stop signal. Changing the context 122 during runtime is generally possible.

Optionally, this aesthetic QR code generation machine can be accompanied by a second machine as shown in **Fig. 7** for generating an image 210 from the QR data 202 and a context 204, such as keyword-like descriptions. In addition to the QR coding and aesthetic image components, the final aesthetic QR code can also include visible written information, such as a name. This makes the aesthetic QR code personalizable and individualizable and can be used for applications with an additional security aspect. For example, third parties can determine for whom a specific aesthetic QR code was created without the need for technical aids.

The image 210 created by the machine of **Fig. 7** can be used as the base image 104 for the machine 100 from **Fig. 6**. This results in several design possibilities: the machine of Fig. 7 can be linked to the machine of Fig. 6 and the 206 hyperparameters can be adjusted by the discriminator 126 together with the other hyperparameters 106, 112 and 118.

As an alternative design option, a separate feedback loop with a human evaluator can be used for image generation, as shown in Fig. 8. The machine in Fig. 8 shows how this works: in step 218, the discriminator 212 presents one or more example images to the human evaluator 216, and the human evaluator provides evaluations to the discriminator 212 in step 214. Based on these evaluations, the discriminator 212 adjusts the hyperparameters 206 of the generator 208. This loop repeats until the human evaluator 218 signals the end of the process via a special stop signal.

The same benefits are achieved for data matrix codes and other two-dimensional barcodes. The process is not limited to QR codes.

## Claims

1. A method for generating a 2D barcode embedded in an image, in particular a DM or QR code, comprising the following steps:

(a) selecting a base image, wherein the base image is divided into cells (11) or modules according to the code grid,

(b) selecting an initial code with a predetermined coding of modules in bits with the bit values (12) black or white as the second image layer, wherein the modules of the initial code are each marked as primary or non-primary,

(c) storing each module of the initial code on the corresponding module of the base image by inserting the respective bit value (12) into the module,

wherein in the case of a primary module of the initial code, this module is completely filled with the bit value (12) if the color or gray values of the graphic content of the module of the base image differ substantially from the bit value (12) of the associated primary module, and

in the case of a non-primary module, a partial area of the module of the base image is filled with the bit value (12),

thereby creating an interim image with modules,

(d.1) Selecting a second base image,

(d.2) Generating a third image layer by assigning transparency values to the modules of the second base image, whereby modules of higher aesthetic importance are assigned a lower transparency value,

(e) Generating the embedded code by overlaying the modules of the third image layer onto the modules of the interim image according to their transparency value.

2. The method according to claim 1, wherein the second base image in step (d.1) is identical or substantially identical to the first base image.

3. The method according to claim 1 or 2, wherein the partial area of the module of the base image in step (c) is a central area of the module, the area size of which is in particular between about 30% and 70% of the area of the entire module, and the circumference of which is further in particular square, square with rounded corners, circular or heart-shaped.

4. Method according to one of the preceding claims, wherein after step (b.1) in the base image areas of higher importance are selected and modules of the initial code are moved from the corresponding area therein to other areas of the initial code while preserving the coded information.

5. Method according to one of the preceding claims, wherein the base image comprises visible pictorial and/or written information.

6. The method according to any one of the preceding claims, further comprising the step of:  
(f) transforming the embedded code by one or more graphical distortions using parameters A,  
(g) testing the scannability of the distorted embedded code,  
(h) either after determining scannability, confirming the embedded code as suitable, or otherwise one or more times:

Generating another base image with changed graphic parameters and/or generating another third image layer with a different assignment of transparency values, as well as

Creating another embedded QR code,

Repeat the scannability test until scannability is determined and the additional embedded QR code is confirmed.

7. The method according to claim 6, comprising:

(f') converting the embedded code into a population of test images by one or more graphic distortions using the parameters A, the parameters A differing from one another in the test images,

(g') Testing the scannability of all test images of the population and determining a recognition statistic,

(h') either after reaching a predetermined success value, confirming the embedded QR code as suitable, or otherwise one or more times:

Generation of a further third image layer with a different assignment of transparency values, and

Generation of a further embedded code,

Repetition of the scannability test of the additional population until the specified success value is reached and the additional embedded code is confirmed.

8. The method according to claim 6 or 7, wherein the parameters A comprise one or more of the following list:

- a. one or more perspective distortions,
- b. warpage of all or part of the embedded code,
- c. artificial reflection of light,
- d. artificial partial or total shading,
- e. soiling and/or damage,

- f. covering or tearing,
  - g. resolution and color spectrum of a physical printer,
  - h. simulation of graphical alienation by printing or screen display of the embedded code.
9. Method according to one of the preceding claims, wherein before step (b) the initial code is modified using predetermined parameters B, which in particular comprise one or more from the list:
- a. Modification of the format version of the code,
  - b. Modification of the form of the modules of the code,
  - c. Modification of the mask of the code.
10. Method according to one of the preceding claims, wherein, before step (a), the base image is modified using predetermined parameters C, which in particular comprise one or more from the list:
- a. Modification of the image section,
  - b. Modification of the resolution of the base image,
  - c. Modification of the brightness and/or contrast of the base image.
11. Method according to one of the preceding claims, wherein after step (e) the embedded code is either confirmed or rejected by an authority using an evaluation, wherein after the rejection steps d.1 and d.2 are repeated one or more times using parameters B and C until the further embedded code is confirmed by applying the evaluation.
12. The method of claim 11, wherein the instance is a person or an AI module, wherein the AI module is trained based on a data set of assessments performed by persons.
13. Method according to one of the preceding claims, wherein: creation of a sequence of embedded codes from a sequence of base images and a common initial code, wherein the sequence of embedded codes is combined to form a film file.