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The Mosaic Sustainable Marker Model for Augmented Reality Systems

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ABSTRACT

The paper proposes the model and the method of forming a mosaic sustainable marker of augmented reality. The advantages and disadvantages of existing augmented reality markers have been analyzed. The basic requirements for augmented reality marker are formulated. The basic stages of building a mosaic sustainable marker of augmented reality are offered. The conformity of the marker with the formulated requirements was checked. Marker recognition accuracy is substantiated, the minimum value of the parameter under which the robustness condition is ensured. The relation, which defines the accuracy of recognition of the AR-marker, taking into account the fact that only part of the pixels are recognized correctly, is specified.

Key words : the model, mosaic sustainable marker, augmented reality systems, the method of forming.

1. INTRODUCTION

Augmented reality (AR) is the augmentation of the physical world through digital data provided by mobile devices or special gadgets (AR glasses) in real time [1]. Augmented reality based on markers uses a camera and special passive visual markers, such as a QR code (quick response code). By detecting markers in a video stream, you can distinguish virtual objects from the real world. It is essential to determine the position of the camera, which is determined by computer vision [1].

According to the forecasts [2-8] for the development of the AR / virtual reality (VR) market by 2025, in terms of turnover and profit, the market will be divided into the following segments (in descending order): games; medicine; education; military use; production and transport; cinema and television; online broadcasts; training and training of employees; marketing and advertising; retail / online commerce; real estate trade. Thus, it can be seen from the analysis [2–8] that in most cases the augmented reality marker systems will be used. Existing markers [2–8] have some drawbacks, and they cannot always be used to solve new problems. Therefore, it is important to search for new augmented reality.

1.1 Problem analysis

It is known that main types of AR markers available [1, 2, 11]:

- the template markers - black and white markers that have a simple image inside a black frame (Fig. 1);

- the 2D barcode markers - markers made up of black and white cells that encode data bit-by-bit, and sometimes frames or sync areas. Most often, QR codes are used as bar code AR markers (Fig. 2);

- the circular markers - similar to barcode markers, only bits are encoded not by rectangular cells, but by black and white circular sectors (Fig. 3);

- the image markers - regular colour images (Fig. 4) are used as markers. May contain frames or other landmarks to identify and locate position. Brand-re-images are usually identified by search help by pattern or by image features.

Analysing the types of AR markers, we can conclude that each of them has its advantages and disadvantages [1, 2, 6-11]:

- they all allow to determine the position of the camera, but for this purpose different methods are used;

- finding the angles of the image (template);

- finding specific areas of anchoring (bar code and circle);

- finding specific points of the image and their descriptors (image);

- some of them (bar code and circular) contain additional information (messages), for example, links on the Internet, which is a clear advantage, because it allows to expand the scope.

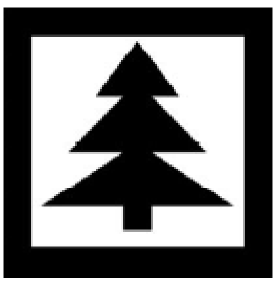

Figure 1: The template marker

Figure 2: The 2D barcode marker

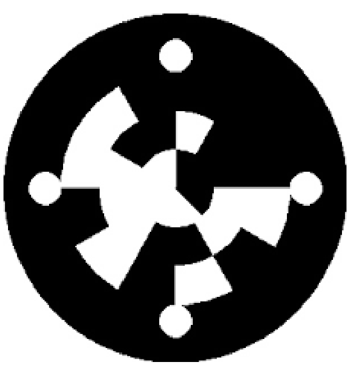

Figure 3: The circular marker

Figure 4: The image marker

2. MAIN MATERIAL

So, let's state the basic requirements for the AR marker:

1) is easily and quickly in the video stream;

2) a minimum number of colours is used, even better - grayscale;

3) contains additional information (message);

4) allows you to determine the position of the camera;

5) paragraphs 3 and 4 are performed when up to 50% of the marker information is lost (for example, when it is closed by a noise interference or the physical absence of any part of the marker).

Obviously, no standard type of AR marker will fully meet the requirements of 1-5.

The closest match is 2D barcode markers, but they do not meet the requirements of robustness 5. We will use the QR code as an image message, it contains only 2 colours and encodes the message (Fig. 5).

Figure 5: The image-message (QR code N = 21, encoded message "Hello, world!")

The following is suggested:

- each pixel of the image-message is magnified k times (replaced by the matrix k × k);

- the pixels in the resulting image are rearranged in a pseudo-random way (Fig. 6);

- create an image container consisting of cells, each of which has the colour of a permuted image;

- to facilitate detection of this image and cell division, we enlarge each cell and insert it into a frame with an intermediate colour - grey; thus it is suggested to use only 3 colours (grayscale).

Figure 6: The permuted image

The image-container thus obtained is proposed to be used as an AR marker (Fig. 7).

Figure 7: The model of the proposed AR marker is a container containing the obtained permuted image, which is shown in Fig. 6; each cell is 8 × 8 pixels in size, including a 1-pixel frame

We will show that all requirements 1 - 5 are satisfied.

1. For the detection of an AR marker in the video stream, it is advisable to use a filter that calculates the local standard deviation per square circle of each pixel of the input image (Fig. 8). In this case, the response of the filter will be maximum at the boundaries between the cells (since we have a guaranteed difference in brightness in half of the dynamic range) and minimal in the middle of the cells (because they are homogeneous areas) and in the background area (for real images, the difference in brightness between neighboring pixels is small due to their strong correlation) (Fig. 9).

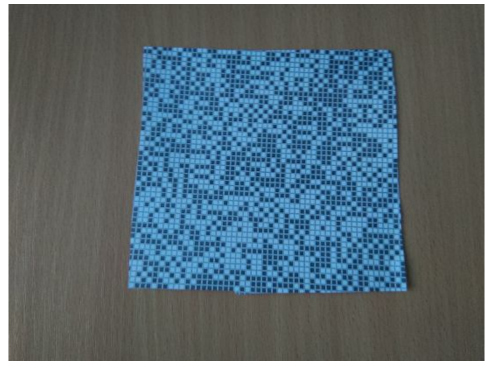

Figure 8: The input image

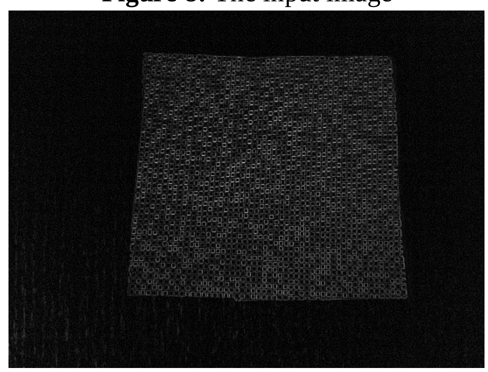

Figure 9: The filter response that calculates local standard deviation

2. As already mentioned, only 3 grayscale grades are used, which simplifies the production of marble and makes it insensitive to changes in light.

3. The message is contained in the QR code.

4. A special algorithm has been developed to determine the position of the camera, which will be described in a separate article (Fig. 10, Fig. 11).

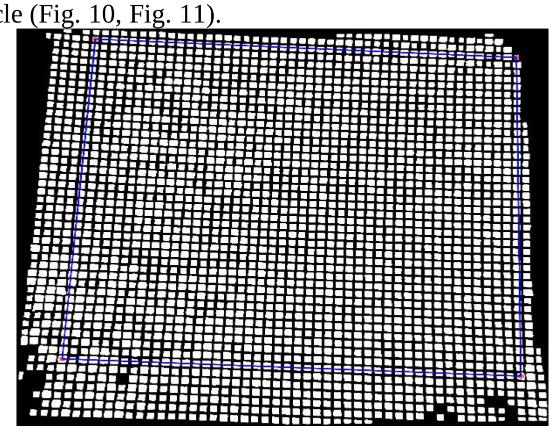

Figure 10: An example of determining the position of the camera: finding the anchor points

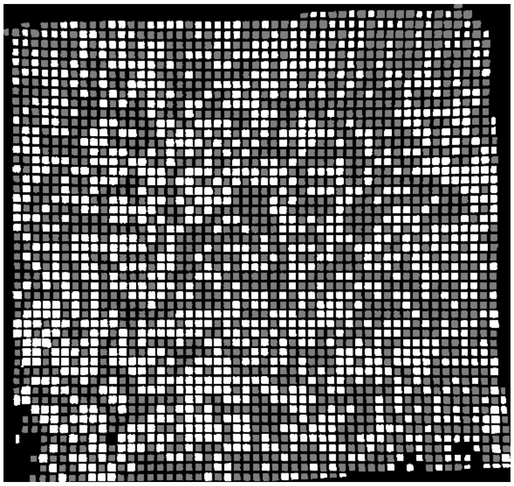

Figure 11: An example of determining the position of the camera

5. The robustness condition is satisfied by post-docking post-processing of the back-permuted image - the color of each cell will be defined as the most common color mode, while uncertain values (resulting from information loss) are ignored.

The results of post-processing are shown in Fig. 12-15.

Figure 12: The pixels of the bit container (Fig. 11) are inserted with the correct off set into the N × N matrix, the undefined values are shown in black, the offset values are by a separate algorithm proposed by the author and will be described in a separate article

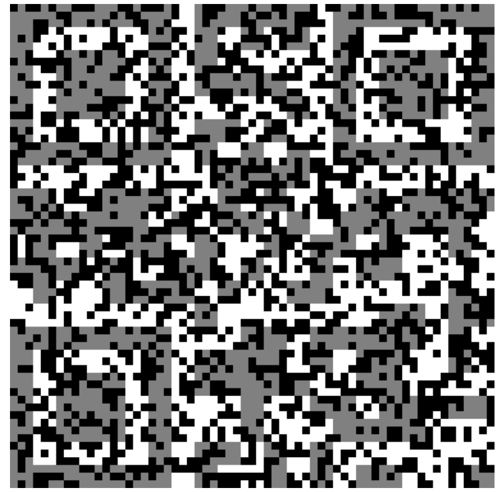

Figure 13: The result of inverse permutation for the previous image

Figure 14: The result of post-processing

Figure 15: The difference between the previous image and the original image of the QR code shown in Fig. 6

We find the condition of correct image reconstruction in the loss of part of the image, it is considered that all the recognized pixels were recognized correctly, i.e. the error arises only due to the loss of part of the pixels. Let the fraction of lost pixels be p, and, as stated above, we duplicated each pixel k^2 times ($k \times k$ matrix). A cell will recover incorrectly if no recognized pixel is found within its cell, and the probability of such an event q is easily calculated (expression (1)):

$$q = (1-p)^{k^2}. \quad (1)$$

Plots of empirical probability of recovery and theoretically calculated are shown in Fig. 16.

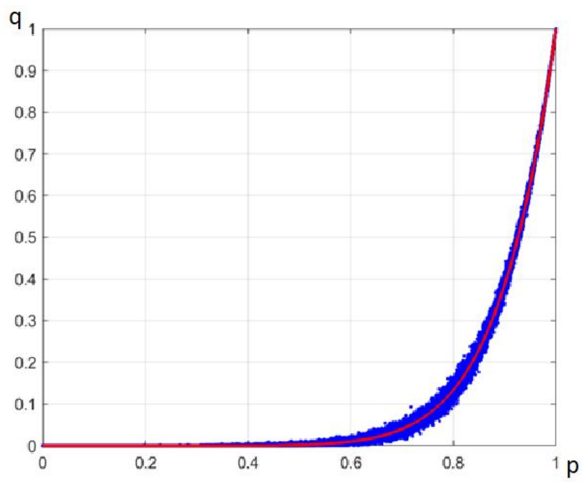

Figure 16: The plots of the empirically calculated probability of recovery (calculated by averaging over 10 experiments, blue dots) and theoretically calculated by formula (1) (red line)

If the QR code is N × N cell size, then the mathematical expectation m of the number of non-renewed cells is (expression (2)):

$$m = qN^2. \quad (2)$$

QR code recognition condition is expression (3):

$$m \le 1. \quad (3)$$

We will assume that due to a certain excess of QR code, 1 unrecognized cell is allowed, in practice the redundancy is ensured by using Reed-Solomon codes, and it is recognized correctly in the absence of more than 1 cell. Rewrite expression (1) using expressions (1) and (2) (expression (4)):

$$(1-p)^{k^2} N^2 \le 1, \quad (4)$$

where the condition for determining k is (expression (5)):

$$k > \sqrt{\frac{-2\ln(N)}{\ln(1-p)}}. \quad (5)$$

The root expression (5) will be positive since you have a p<1, hence log (1-p) <0. For the QR code, the minimum value of size N = 21, therefore, at p = 0.5 (requirement 5), we obtain by expression (5) that the minimum value is k = 3.

5. CONCLUSION

In this paper it is stated that at present the most promising is the use of augmented reality marker technologies and the advantages and disadvantages of the main types of AR markers are identified. Based on the analysis, 5 requirements have been formulated, which should meet the promising AR-marker. The method of constructing an AR marker is offered, which, unlike the existing ones, satisfies all the requirements.

The accuracy of recognition of the AR-marker is theoretically substantiated depending on the relation between its parameters (expression (4)). The minimum value of the parameter k=3 is found such that the robustness condition (expression (5)) is provided. In the following, it is necessary to clarify the relation (expression (4)), which defines the accuracy of recognition of the AR-marker, taking into account the fact that only part of the pixels are recognized correctly.

Areas of further research are:

1) development of a method for determining the parameters of the projective transformation, which is necessary for the alignment of the image and determining the position of the camera;

2) development of the method of finding the correct offset of the aligned image in the N × N matrix, which is necessary for the correct decoding of the permuted image.

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