Image reconstruction using the modified texture synthesis algorithm

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Abstract. The article discusses a method for image reconstruction based on the search for similar blocks using a texture synthesis algorithm. The effectiveness of the new approach is shown using several examples for various areas with lost pixels. The subject of the research is methods and algorithms for processing space-time reconstruction of two-dimensional signals based on a geometric model of images. The object of research is a set of test static images. The result of the study is a modification of the image reconstruction method based on the search for similar blocks in order to reduce the error in image reconstruction. The novelty of the work is an algorithm that improves the quality of image restoration. The results obtained make it possible to reduce the root mean square error.

1. Introduction
Estimation of the true values of image pixels is necessary to one degree or another in most digital image processing tasks. This problem is especially relevant in the automatic processing of images obtained in light-sensitive matrices in digital cameras and video cameras and machine vision systems. Methods for recovering two-dimensional signals find their application in the tasks of processing archival documents in the form of images with various distortions (for example, scratches, spots, dust, unnecessary inscriptions, fold lines) [1-5]. Currently, there are various digital processing methods aimed at solving the problems of restoring partially lost image areas, but their effective use requires significant amounts of a priori information about the useful image. Significant restrictions on the amount of a priori information, which occurs in practice, significantly complicate both the choice of an effective processing method and its values of the optimal parameters [5-10]. In this connection, image reconstruction is an important area of application of modern digital computing technology in order to obtain a reliable estimate for visual and especially automatic analysis. The aim of the research is to reduce the error of image reconstruction by a modified image reconstruction method based on the search for similar areas. Research objectives: Develop a method for image restoration based on the search for similar blocks. Analyze the results of the proposed method.

2. Proposed method
The proposed method of image reconstruction based on the search for similar areas consists of several stages [3]. At the first step, damaged areas of the image are automatically determined or a mask of defective areas is formed by the user. In the second step, the image with the lost areas is restored using the EBM method (exemplar based method) [4]. This method allows you to correctly restore the lost areas using the created mask, correctly reconstructing the pixel values. The method is based on calculating the priority for each pixel of the border with the subsequent search for a similar square block.
in the area of available pixels and copying it to the area of missing pixels. Next, the priority $P(p)$ is calculated for each pixel of the border, which consists of two factors (Figure 1) (1-2):

$$P(p) = C(p) \cdot D(p)$$

$$C(p) = \frac{\sum_{q \in \Omega} C(q)}{|\Omega|}, \quad D(p) = \frac{\|\nabla I_p \cdot n_p\|}{\alpha}$$

where $p$ – the current pixel is at the border of the available pixels; $C(p)$ – trust data; $D(p)$ – gradient data; $|\Omega|$ – the number of pixels of a square block centered at pixel $p$; $\nabla I_p$ – vector orthogonal to the gradient at point $p$; $n_p$ – vector orthogonal to the boundary $\partial S$ at point $p$; $\alpha$ – normalized multiplier, for black and white images is 255.

![Figure 1. Constructing orthogonal vectors](image1)

The computation of the priority allows us to give more weight to the pixels located at the brightness differences (boundaries), thus restoring them first. There is a search for block $\Psi_p$ with the maximum priority of $p = \arg \max_{p \in \partial S} P(p)$. Taking into account the confidence data $C(p)$ allows assigning less weight to the restored pixels with an increase in the distance from the available pixels from the area $S$. Initially, it is assumed that the value of the confidence data $C$ for pixels from the $S$ region is 1, and for the $\tilde{S}$ region is 0. The next step is block $\Psi_q$ is located in the region of accessible pixels $S$, for which the Euclidean norm is minimal (Figure 2) [5] (3):

$$\sqrt{\sum (\Psi_p - \Psi_q)^2} \rightarrow \min.$$  

![Figure 2. Search for similar blocks](image2)
The pixel values from the found block are copied to the $\bar{S}$ area. The confidence data $C$ for the restored pixels is assigned equal to the current value $C(p)$ with the constraint is $\Psi$, that $\forall p \in \Psi_p \subset S$.

The procedure for recalculating the priority and searching for similar areas with subsequent replacement is repeated [6].

Despite the ability of this method to restore the boundaries of objects, this method has the following disadvantages: Visibility of borders on the restored image between found similar blocks. Incorrect recovery in the absence of a similar block. Sensitivity to the choice of block size.

In order to eliminate the above disadvantages, a modification of the image reconstruction method based on the search for similar areas is proposed.

In this paper, we propose an algorithm [7], hat overcomes some of the disadvantages of the method based on the search for similar areas. To eliminate the drawback associated with the visibility of the border when copying blocks, it is proposed to use the block gluing method. Based on the research results, it is proposed to use the texture synthesis algorithm proposed by Efros and Leung. This allows you to optimize the areas of overlap between blocks (Figure 3).

The algorithm of the proposed modified method can be represented in the form of a block diagram shown in Figure 4.

![Figure 4. Block diagram of the proposed modified method.](image)

The algorithm consists of the following steps, shown in Figure 4.

The following are the results of processing the modified methods on test images for various areas with lost pixels. Figures 5 and 6 show the result of processing by the proposed method and EBM.

Analysis of the results shows that the proposed method makes it possible to effectively recover lost blocks. The efficiency of the original and modified method is presented in Table 1.
Figure 4. General block diagram of the modified image reconstruction method

Figure 5. The image reconstruction result:

a) original image, b) image with a mask of distorted pixels, c) image restored by the original method, d) image restored by the proposed method
Figure 6. The image reconstruction result:
a) original image, b) image with a mask of distorted pixels, c) image restored by the original method, 
d) image restored by the proposed method

Table 1. RMSE and MOS dependencies for different image classes

| Images | EBM | Modified EBM |
|-------|-----|---------------|
|       | RMSE | MOS | RMSE | MOS |
| Images | | | | |
| 1.png | 16,1580 | 3,2 | 15,3554 | 3,4 |
| 2.png | 7,4266 | 3,4 | 8,1420 | 3,3 |
| 3.png | 8,8954 | 3,4 | 8,8271 | 3,5 |
| 4.png | 19,1273 | 4,2 | 17,5780 | 4,5 |
| 5.png | 10,0541 | 2,8 | 9,7624 | 3 |
| 6.png | 3,5852 | 2,8 | 4,3571 | 2,7 |
| 7.png | 12,9249 | 2,4 | 12,1123 | 2,5 |
| 8.png | 6,7194 | 4,6 | 6,8761 | 4,5 |
| 9.png | 15,0586 | 2,6 | 14,6051 | 2,8 |
| 10.png | 10,8344 | 3,8 | 10,6106 | 3,9 |
| Average estimates | 11,07839 | 3,32 | 10,82261 | 3,41 |

3. Analysis of the effectiveness of the reconstruction method
For quantitative evaluation of the work of a method is used the random mean square error (RMSE). This quality criterion is common enough to distinguish between a pair of data. The observed image and the original image are used as input [8].

The RMSE expression shows how to obtain the numerical value of a given quality criterion (4) [9].

\[
RMSE = \sqrt{\frac{\sum_{i=1}^{n} (X_{o,i} - X_{i})^2}{n-1}}
\]

In the expression \(X_{o,i}\) - the observed image. That is, this is the image that needs to be compared with the original. Second component of \(X_{o,i}\) - original image. The \(n\) parameter indicates the number of pixels involved in the formation of the image. That is, the pixel-by-pixel difference is used to determine the RMSE estimate. If the image is in color, then it is split into color components (usually RGB).

4. Conclusion
The paper presents a modified image reconstruction method based on the search for similar areas. To eliminate the drawback associated with the visibility of the border when copying blocks, the block gluing
method was used. The examples presented in the work demonstrate the efficiency of the algorithm for various areas with lost pixels.

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