ON A MODIFICATION OF THE FREQUENCY SELECTIVE EXTRAPOLATION METHOD

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Abstract: *In this paper is described a method for automatic analysis of missing block neighbor area. The analysis, which is based on Canny edge detection and calculation of homogeneity coefficient in missing block neighbor area, provides suboptimal rectangular support area for each block. The suboptimal support area for each block is used in Selective Extrapolation algorithm. Paper includes experiment results of proposed method which are compared with results of selective extrapolation where the support area size is fixed for all blocks.*

Keywords: *Image processing, selective extrapolation, Canny edge detection, missing blocks concealment.*

Introduction

Image and video compression standards such as JPEG, MPEG, H.263 [Stockhammer, Hannuksela, 2005] are used for efficient data transmission and representation over the internet. In these standards the data is coded by block based techniques. In case of JPEG the image is segmented into non-overlapping blocks. After segmentation each block is compressed, then stored or transmitted over communication channels. The transmission over the fading channels may lead to transmission errors. If the block is well compressed the error of one bit may cause loss of a whole block. After such erroneous transmission the image may contain block losses. Concealing of block loses is important problem in the image processing.

A powerful algorithm, based on signal extrapolation, is Frequency Selective Extrapolation [Kaup, et all, 2005], which operates in the Fourier domain and has high extrapolation quality. The Frequency Selective Extrapolation algorithm conceals block losses by estimating lost areas from correctly received adjacent areas.

In algorithm of selective extrapolation the support area size for missing blocks is predefined. Missing block surrounded by fixed number of known pixels in each direction forms the support area. Therefore, the missing block is located in the center of support area. But if the support area is not homogeneous, some parts of it may negative affect on the results of the extrapolation. To overcome that problem we analyze the support are in each direction and choose suboptimal size of it. Then the suboptimal sizes of support areas are used in Selective extrapolation algorithm.

The paper organized as follows: In the Section 2 the theory of frequency selective extrapolation is shortly described. Then, in Section 3 the proposed algorithm of support area analysis is described and step by step algorithm of selective extrapolation. In Section 4 the results of the experiments are shown and in Section 5 we conclude the work and summarize our future plans.

Frequency Selective Extrapolation Overview

Fig. 1 schematically shows example of area Λ which is a part of digital image, where missed block has occurred. Λ area is composed of dark grey area **B** (missing block area), which has to be estimated by extrapolation of elements in light grey area **A** (support area).The part of image, which is contained in the area Λ we denote F = {f[m,n]}, where $m = \overline{0, M-1}$, $n = \overline{0, N-1}$. In order to extrapolate the observed area Λ elements of the known area are approximated by the parametric model $G = \{g[m,n]\}$, which is also defined in Λ

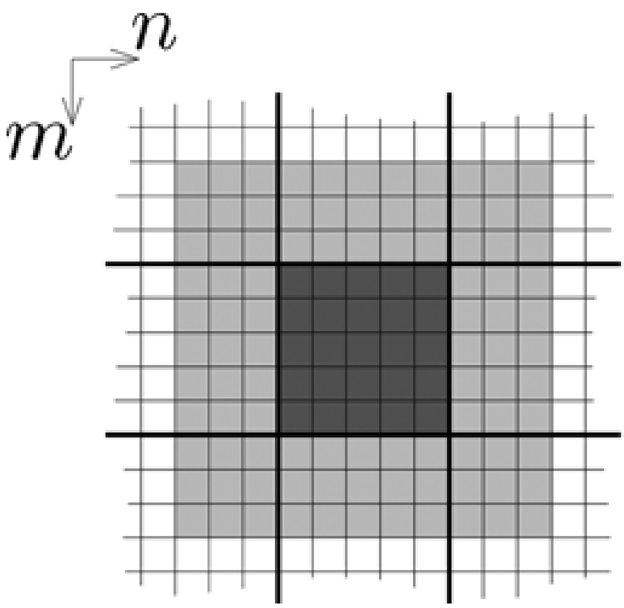


Fig.1: Part of digital image with missing area

The parametric model is a weighted liner combination of basis functions. In this algorithm as basis functions 2D DFT functions are used. The parametric model is generated successively, in each iteration we calculate $g^{(v)}[m,n] = \sum_{(k,l)\in K^v} c_{k,l}^{(v)} \varphi_{k,l}[m,n]$, where K^vrepresents a set of basis functions used for the expansion of the parametric model $g[m,n]$, before iteration v. $c_{k,l}^{(v)}$is expansion coefficient which is calculated in iteration v. $\varphi_{k,l}[m,n]$ is DFT basis function which is defined in entire area Λ.

$$\varphi_{(k,l)}[m,n] = e^{(j\,2\pi/M\,mk)}\, e^{(j\,2\pi/N\,nl)}, \qquad j = \sqrt{(-1.)}$$

For each iteration a residual error is calculated

$$"r^{((v))}[m,n] = (f[m,n] - g^{((v))}[m,n])\,b[m,n]" ,$$

where $b[m,n]$ is the window function

$$b[m,n] = \begin{cases} 1, (m,n)\epsilon A \\ 0, (m,n)\epsilon B \end{cases} .$$

In each iteration the residual error of support area is decreased by $\Delta g[m,n]$, which shows the change of parametric model between iteration steps $v$and $v+1$,$\Delta g[m,n]$ is updated in each iteration. Then, the residual error is calculated in the following way: $r^{(v+1)}[m,n] = r^{(v)}[m,n] - \Delta g[m,n]b[m,n]$.

The $c_{k,l}^{(v)}$ expansion coefficient is calculated for minimizing weighted instantaneous residual error energy E_A (1). For iteration step $v+1$ the residual error energy is calculated in following way:

$$E_A{}^{(v+1)} = \sum_{(m,n)\epsilon\Lambda} w[m,n]\left(r^{(v)}[m,n] - \Delta g[m,n]\right)^2 , \qquad (1)$$

where

$$w[m,n] = \begin{cases} 0, when\,(m,n)\epsilon A \\ positive\ value, when\ (m,n) \in B \end{cases}$$

$\Delta g[m,n]$ is updated in the following way:$\Delta g[m,n] = \Delta c\varphi_{u,v}[m,n]$,where$\Delta c$ is optimal update of expansion coefficient in each iteration, (see, [Kaup, et all, 2005]). The expansion coefficient $c_{u,v}$ is updated as:

$$c_{u,v}^{(v+1)} = c_{u,v}^{(v)} + \Delta c \qquad (2)$$

The pair (u,v) is included in the set of basis functions K^{v+1}, if a function with such coefficients was not included before: $K^{(v+1)} = K^{(v)} \cup (u,v), \text{if}\,(u,v) \notin K^{(v)}$

The error energy is updated in following way, see [Kaup, et all, 2005]

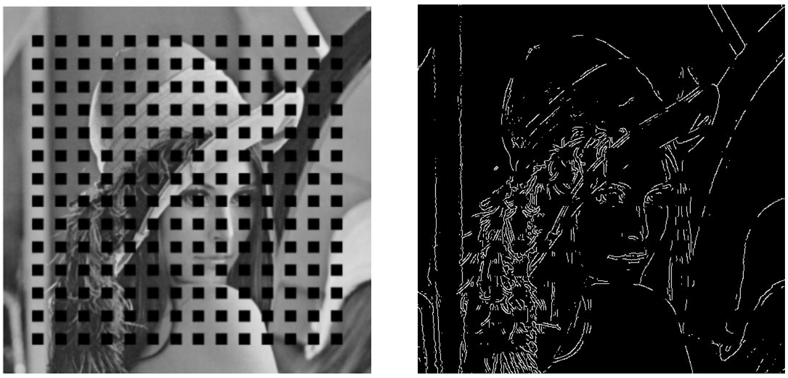
$$E_A{}^{(v+1)} = E_A{}^{(v)} - \Delta E_A{}^{(v+1)} \qquad (3)$$

From equation (3) we see that $E_A{}^{(v+1)}$ has minimum value, when $\Delta E_A{}^{(v+1)}$ has maximum value.

$(u,v) = \text{argmax}\,\Delta E_A{}^{(v+1)}$

Modification of selective extrapolation algorithm

We need to define support areas for each missing block. The definition of support area sizes is made by analysis of missing block neighbor area. We analyze the copy of input image, which is shown in Fig.2 (a), processed by Canny edge detection algorithm [B.Jahne, 2005] Fig.2 (b). The processed image has only white and black pixels. White pixels are equal to 1 and show the edges of input image. The black pixels are equal to 0 and show regions of image that have high homogeneity.



(a) (b)

Fig. 2 (a) Input Image (b) Copy of input image processed by Canny algorithm

For estimation of support area we calculate coefficient of homogeneity (COH) by following formula

$$COH = \frac{(number of white pixels)}{(number\ of\ all\ pixels)} * 100.$$

We analyze the neighbor area of missing block in each direction and define number of surrounding supporting pixels for it. Fig. 3 shows missing block (black area) which has $(x, y), (x_1, y_1)$.For analysis of support area we use 4 types of windows for each direction. The coordinates of those windows are given below:

Left Side: $(x-(k+1)m, y-m),\ (x-km, y_1+m)$;

Right: $(x_1+km, y-m),\ (x_1+(k+1)m,\ y_1+m)$; (4)

Top: $(x-m, y-(k+1)m),\ (x_1+m,\ y_1-km)$;

Bottom: $(x-m,\ y_1+km),\ (x_1+m, y_1+(k+1)m),\ \ 0 \le k \le 4.$

Example of left side window is shown in Fig. 3, where A_0 is window for k=0

and A_1 for k=1.

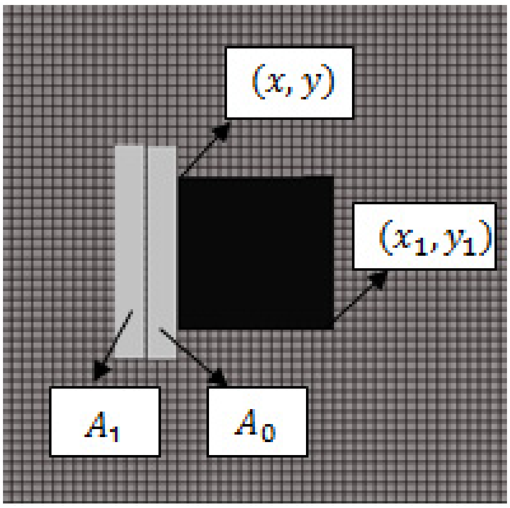


Fig. 3: Missed block (black), analyzed areas (light grey)

For each side of support area we calculate the absolute value of difference of COH for neighbor windows A_k and A_{k+1}:

$\Delta = |COH(A_{k+1}) - COH(A_k)|$.

If $\Delta \leq 5$, we calculate Δ for A_{k+1} and A_{k+2}. We continue this until k=4 or $\Delta > 5$ .After termination for current side of support area, we obtain the number of support pixels. The number of pixels is equal to (k+1)m, where m is fixed number. Then, we implement the same algorithm for all sides of missing block support area. The number of surrounding supporting pixels for all sides we record in array. After implementation of the algorithm for all missing blocks we pass the array of support area parameters to modified selective extrapolation algorithm.

The step by step algorithm is given below:

Implementation of Canny edge detection algorithm on copy of input image

Record support area sizes for all blocks in array, pass the array to selective extrapolation algorithm

Selective extrapolation algorithm is initialized with $g[m,n]^{(0)} = 0$ and the residual error equals to weighted original signal in the first iteration: $r_w^{(0)}[m,n] = w[m,n]f[m,n]$. Where,

$$w[m,n] = \begin{cases} 0.74\sqrt{\left(m - \frac{M-1}{2}\right)^2 + \left(n - \frac{N-1}{2}\right)^2}, (m,n)\epsilon A \\ 0, (m,n)\epsilon B \end{cases}.$$

Then, we transform $w[m,n]$ and $r_w^{(0)}[m,n]$ into frequency domain by Fast Fourier Transform algorithm [Brigham, Morrow,1967].

$\Delta E_A{}^{(v+1)}$ energy decrease computation.

Selection of basis functions with indexes (u,v).

$c_{u,v}^{(v+1)}$ coefficient update for Δc, see equation (2).

Check if the $\Delta E_A{}^{(v+1)}$ is less then predefined E_{min}=15 threshold or if the number of iterations is more then 11. If no go to step 2 else go to step 6.

The algorithms terminates and we get parametric model by Inverse Discrete Transform of $G^{(v)}[k,l]$:$g^{(v)}[m,n] = IDFT_{M,N}\{G^{(v)}[k,l]\}$.

In the end elements of the missed block of input $f[m,n]$ image are replaced with corresponding elements of $g^{(v)}[m,n]$ parametric model.

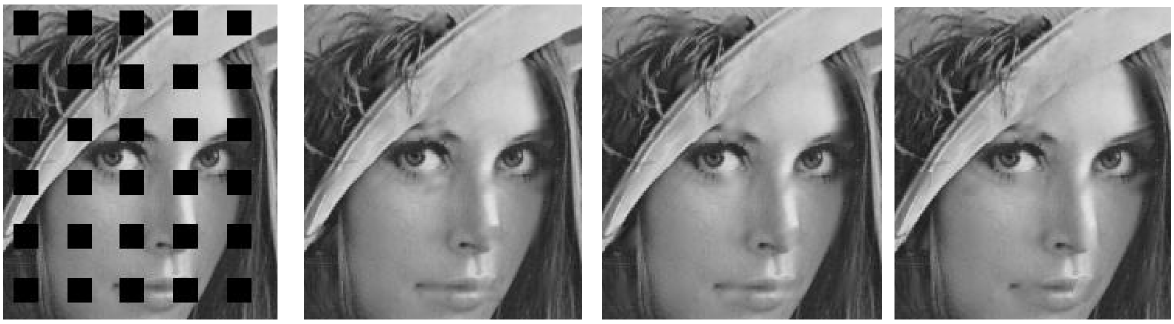
The algorithm is implemented in Matlab. Fig. 4 shows the result of the selective extrapolation algorithm.

(a)................................(b)

Fig.4 (a) Input image with missing blocks; (b)Concealed Image.

Experiment results

We have implanted the proposed algorithm and compared it with result of selective extrapolation algorithm. The size of missing block is 16x16. The value of m in (4) is equal to 3px. The PSNR value is calculated only for extrapolated regions.



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

Fig. 5: (a) Input image with missing blocks; (b) concealed image by Selective Extrapolation (SE) with fixed 8px support area PSNR: 23.13dB; (c) concealed image by SE with fixed 16px support area. PSNR: 23.50dB; (d) concealed image by proposed method. PSNR: 23.61dB.

Fig.5 shows the result of proposed method picture (d) which is compared with results of Selective Extrapolation method (b), (c). The Selective Extrapolation algorithm was implemented for different sizes of support areas.

We have paid attention on not homogeneous regions such as region of eyes and compared the results of proposed method with results of SE method. We can see that in not homogeneous regions by proposed algorithm is obtained significantly higher PSNR value in comparison to methods we the support area size is fixed.

(a) (b) (c)

Fig. 6: (a) Input image with missing blocks; (b) concealed image by SE with fixed 16px support area. PSNR: 21.53dB; (c) concealed image by proposed method. PSNR: 22.28dB;

The experiment results show that the proposed method is effective and for not homogeneous regions provides high quality of extrapolation.

Conclusion and future work

In this paper was described modification method of frequency selective extrapolation. The modification based on support area analysis is targeted to choose suboptimal size of support area. The usage of Canny algorithm allow us easily detect the edges of input image, thus to calculate coefficient of homogeneity.

The results of the experiments have shown that the method is effective. We have shown that the size of support area affects the quality of extrapolation. In our future work we are going to improve the support area analysis technique. Moreover, in the frequency selective extrapolation method discrete Fourier transform (DFT) is used, we are going to use other transformations such as Haar, discrete cosine transform (DCT) and Hadamard transform [S.Agaian, et all, 2011].

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