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METHOD FOR PREPROCESSING A DISTORTED IMAGE BASED ON THE DECONVOLUTION PROCEDURE

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Abstract. In the article conducted the review of solution to the deconvolution problem is to reverse a two-dimensional convolution. The term "deconvolution" covers the most important and widely used image processing methods. The need for such an operation arises in all areas of science related to measurements. There are a large number of papers on deconvolution methods.The deconvolution problem can be solved in several ways. The choice of the most suitable method for solving this problem depends on a number of factors, including the shape and extent of the point propagation function (FRT), the nature of the original image, and the degree of truncation by the frame window of the recording device.

Keywords: method for preprocessing, a distorted image, based on the deconvolution procedure.

Introduction. Whatever method is used, it is almost always necessary to pre-process the specified distorted image to transform it into a form that is convenient for performing the deconvolution procedure. Preprocessing can be divided into five categories: smoothing, partitioning, Apodization (weighing the signal segment to be processed with a weight function), boundary expansion, and super-resolution. Image smoothing here refers to noise reduction. Partitioning involves splitting an image with a spatially dependent FRT into fragments, in each of which the FRT can be approximated as spatially invariant. Apodization is a method to reduce the impact of a frame window (recording device) that truncates an image. However, this method may be less effective than the border extension method, which we have successfully applied in a number of cases. There are two modifications of the method of expansion of borders is a simple extension of the with overlapping. The second method is generally preferred because it takes advantage of the consistency condition of periodic convolutions. This is another example of how the efficiency of the numerical method increases when the features of the problem under study are more fully taken into account in terms of mathematical physics. Over-resolution is considered a pre-processing procedure because it ultimately reduces noise.

There is also multiplicative deconvolution, which is the most common method for restoring an image that is represented as a consistent convolution. A distorted image that is not one should be converted to a consistent convolution view.

The method of subtractive deconvolution is particularly useful when the defects present in the recorded image are not associated with loss of resolution, but with distortion of small details, for example, when the FRT has the same narrow main lobe as the resolved part, but has a wide tail of significant amplitude or is characterized by high side lobes. The subtractive deconvolution method can be easily modified to include space-dependent distortions, although the computational implementation of these methods then becomes very complex.

There are different approaches to the deconvolution problem. These approaches include non-recursive and recursive filtering methods in the image plane, direct matrix methods, and maximum entropy and maximum likelihood methods.

The coordinated deconvolution method, which originated from studies of complex zeros in the frequency plane, is basically a one-dimensional method that can be as widely applied as the multiplicative deconvolution method.

Materials and methods. One of the most important practical methods of deconvolution is the method of blind deconvolution. Note that all methods of processing speckle images can be considered as special cases of blind deconvolution.

In addition to the well-known traditional applications of deconvolution, there are also various exotic applications of deconvolution. One of the most remarkable applications is the restoration of recordings of famous singers voices on old gramophone records by blind deconvolution.

The convolution integral is represented by the expression

$$b(x) = f(x) * h(x) \tag{1}$$

where $h(x)$is the function that sets the distortion; $f(x)$ is the function that needs to be restored.

According to the Fourier convolution theorem, the image of a quantity (1) is equal to

$$B(u) = F(u)H(u) \tag{2}$$

where $F(u)$ is the function associated with the function f(x) by a two - dimensional Fourier transform; $H(u)$ is the Fourier image of the optical transfer function.

The idealized problem of finite deconvolution is as follows: the functions $b(x)$ and $h(x)$ are given, and the function $f(x)$ must be restored, provided that all three quantities have a finite extension.

It follows from the relation (2) that this problem can be solved as follows

$$b(\mathrm{x}) = f(x) * h(x) \tag{3}$$

The division operation inside curly brackets in expression (3) is called simple inverse filtering. The term "filtering" is used here by analogy with the classical theory of circuits and the modern theory of signal processing. A classic filter is a device that changes the spectrum of time frequencies of a signal. The spectrum $B(u)$ is a function of the spatial frequency.

The optical transfer function $H(u)$ changes the spatial frequency spectrum $B(u)$ as a result of applying the above division operation.

Since processed images are usually stored in computer memory as quantized values, image processing techniques typically use digital rather than classical analog filters. A digital filter is defined by a discrete array, generally speaking, of complex numbers, which changes the spectrum of spatial frequencies during some processing operation. Therefore, both functions, h(x) in formula (1) and $H(u)$ in formula (2), can be considered as filters (and in most applications they are implemented digitally). The generally accepted classification of digital filters originated in the theory of signal processing as functions of time, and this classification can be used in the theory of processing one-dimensional images, i.e. signals as functions of a (single) spatial variable. We will transfer the corresponding terminology to the two-dimensional case. The concept of "reference" in the theory of signal processing passes into the concept of "image element" in the theory of image processing. Both samples and image elements must be quantized in amplitude before they are digitally processed. The image to which the filtering operation is to be applied is called the specified image, and it is referred to as consisting of the specified image elements. Elements of a filtered image are called output image elements. In the case of a non-recursive digital filter, each output image element is a weighted sum of the specified image elements. In the case of a recursive digital filter, each image output element is a weighted sum of the specified image elements and the previously calculated image output elements. All practically implemented digital filters, of course, are described by arrays of finite sizes (in the one-dimensional case, the final filter is often called a short one). A digital filter is called a direct filter if it is applied in the image plane, and a spectral filter if it is applied in the frequency plane. The causal filter is one-way in the sense that its response always lags behind the input action (this is somewhat artificial in the two-dimensional case, but of course is very important for one-dimensional filtering operations that are the basis of signal processing as functions of time). Causal filters are almost always implemented as direct filters. A multiplicative digital filter is a spectral filter in which each output sample is obtained as the product of a given input signal element by one element of the filter array.

If all the essential aspects of the practical problems of deconvolution were reduced to the formula (3), then the entire content of this publication could easily be contained in a small article. However, there are many practical difficulties in the deconvolution problem. This is because the data being processed is always distorted in practice.

Before setting the practical problem of deconvolution, we examine some properties of convolution consistency.

In the one-dimensional case, the ratio (2) is represented as

$$B(w) = F(w)H(w) \tag{4}$$

where the real variable u is replaced by the complex variable $B(w)$. If the functions $f(x)$ and $h(x)$ have a finite extension, so that the extension of the function $b(x)$ is also finite, then their spectra are characterized by sets of zeros in the complex w-plane. If a given set $z_g$is represented as a set of real zeros z_{gr} and zeros that can be complex z_{gc}, then we can write

$$z_b = z_f \cup z_k \tag{5}$$

This means that the one-dimensional deconvolution problem is consistent only if all zeros of the function $H(w)$ are also zeros of the function $B(w)$. Therefore, the values $b(x)$ and $h(x)$ cannot be set independently; it must be known beforehand that they satisfy the relation (1). The same applies to two-dimensional convolutions.

Results. Now let's go back to the periodically extended (overlapping) ideal distorted imb(x) image and Its IMB(x) spectrum . The latter can be written as

$$M_b(x) = \sum_l^{\infty} \quad F_l \; H_{l,m} \delta(L_1 u - l)\delta(L_2 \gamma - m) \tag{6}$$

where $\delta\ (*)$ is the Delta function; Fi, m are the Fourier coefficients of the true image $f(x)$, which are also counts of the function $F(u)$which are considered in the counting theorem. These samples are taken at raster points (l/L_1 , m/L_2) in the frequency plane. The values Hl, m included in expression (6) are samples of the optical transfer function $H(u)$, at the same points in the raster:

$$H_{l,m} = H(\frac{1}{L_1}, \frac{m}{L_2}) \quad (7)$$

where l and m are arbitrary integers.

Now we can set an idealized problem of periodic deconvolution: given the functions $imb(x)$, and $h(x)$, we need to find the function $f(x)$, [knowing that $f(x)$, and $f(x)$, are functions of finite extension, and $imb(x)$ is a periodic function].

For a given function b (x), you can calculate the function B (u) and immediately find that

$$H_{p,l,m} = B(\frac{1}{L_1}, \frac{m}{L_2}) \quad (8)$$

Similarly, the counts of the optical transfer function Hl, m are calculated . The expression (6) shows that each value of F_l, m is given by a division $\frac{B_{p,l,m}}{H_{p,m}}$ operation, which can always be performed if the values of Hl , m are different from zero. This simple approach is adequate in the case of functions $b(x)$ and $f(x)$, which are selected independently, since the function $imb(u)$ in accordance with expression (6) actually exists only at the above points in the raster. But this approach is not acceptable in an idealized problem in the case of finite convolution, since then $B(u)$, is a continuous function of the variable u.

It is therefore surprising that the only consistency condition for periodic convolutions is the requirement that the values $H_{l,m}$ can be zero only for those values l and m for which $H_{l,m}$=0. This condition is called the consistency condition for periodic convolutions. We emphasize that there is no value. $H_{l,m}$ cannot be exactly zero in the real measurement of the function $h(u)$, or, equivalently, the function $H(u)$, so that periodic convolutions are always consistent in practice (they are, of course, very noisy when a large number of values $H_{l,m}$ are "small" at values l and m that correspond to values significantly different from zero $B_{p,l,m}$).

The practical problem of deconvolution is set as follows: the functions $b(x)$, and $h(x)$ are given , you need to find the function $f(x)$, knowing that it is a truncated version of the function of the recorded image $r(x)$.

One of the "Golden rules" in image reconstruction is to avoid processing data that contains any discontinuities, of which clipping and truncation are the most undesirable, since they almost always produce false details (often called artifacts, especially in medical applications). Thus, as a rule, it is desirable to pre-process the image in order to fully compensate for all existing gaps and other removable defects.

Conclusion. Any type of preprocessing can, of course, contribute noise in addition to the image distortion f(x) already present in the recorded image $r(x)$. But if the gaps are not fixed, then the corresponding artifacts usually prevail over any additional noise introduced by preprocessing. The" aligned " shape of the image is denoted here by $a(x)$.and will be called a pre-processed recorded image. Although all three values must change as a result of preprocessing, there is rarely any way to estimate how much, and therefore it usually makes no sense to talk about the difference between images $a(x)$ and $r(x)$. Next, we will treat these two images as identical, at least in the frame a (i.e., in the area of the image plane) where the pre-processed version of the meaning image fits $a(x)$. Therefore, we assume that

$$a(x) = f(x) * h(x) + c(x) \quad (9)$$

This assumption does not affect the generality of reasoning, since noise c(x) includes the effects of arbitrary additive distortion associated with preprocessing.

Now we will introduce the concept of "recoverable true image $\hat{f}(x)$ This is an estimate of the image $f(x)$ that can be obtained from the image $h(x)$.

In any rational approach to solving a practical deconvolution problem, the pre-processed image a(x) is first obtained from the specified image $a(x)$. Then, a suitable deconvolution procedure is selected to obtain $\hat{f}(x)$ based on h(x) and a(x). Some of these procedures can be seen as the process of obtaining $\hat{h}(x)$ a modified point propagation function that is associated with a pre-processed recorded image and a recoverable true image ratio

$$a(x) = \hat{f}(x) * h(x) + c(x) \qquad (10)$$

It is convenient to denote the Fourier coefficients $\hat{f}(x)$ of a function by, and to denote the spectra $\widehat{F_{l,m}}$ of functions $a(x)$, $c(x)$, and use $\hat{f}(x)$ $\hat{h}(x)$ the corresponding capital letters with or without a" hat".

If there is a concern that the differences between $\hat{f}(x)$ and $f(x)$ will greatly increase due to the lack of consistency between the functions $a(x)$ and $h(x)$, taken explicitly finite, then you can refer to the formula

$$im_b(x) = \sum_{l,m \to \infty}^{\infty} b(x - lL_{1,}y - mL_2)$$

for a periodic $imb(x)$ image with b replaced by a . Then the imb_u spectrum of the convolution is given by expression (6), but with the replacement of the values $\widehat{F_{l,m}}$ and $\widehat{H_{l,m}}$ the values F_l, m and H_l, m, respectively. Recall that periodic convolutions are not affected by inconsistency, which, as already mentioned, can distort convolutions of quantities that have finite extensions.

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СПОСОБ ПРЕДВАРИТЕЛЬНОЙ ОБРАБОТКИ ИСКАЖЕННОГО ИЗОБРАЖЕНИЯ НА ОСНОВЕ ПРОЦЕДУРЫ ДЕКОНВОЛЮЦИИ

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Аннотация. В статье проводится обзор решения задачи деконволюции, которое заключается в обратном обращении двумерной свертки. Термин "деконволюция" охватывает наиболее важные и широко используемые методы обработки изображений. Необходимость в такой операции возникает во всех областях науки, связанных с измерениями. Существует большое количество работ, посвященных методам деконволюции. Проблему деконволюции можно решить несколькими способами. Выбор наиболее подходящего метода решения этой задачи зависит от ряда факторов, в том числе от формы и протяженности функции распространения точки (FRT), характера исходного изображения и степени усечения кадровым окном регистрирующего устройства.

Ключевые слова: метод предварительной обработки, искаженное изображение, процедура деконволюции.