Halftone based approach towards show-through removal of scanned document images

A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD DEGREE OF

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PRINTING ENGINEERING & GRAPHIC COMMUNICATION

by

SOURAV SINHA

Class roll number:001411602008

Exam roll number:M4PRI1605

REGN. NO. –129441 OF 2014-2015

UNDER THE SUPERVISION OF

Dr.Arpitam Chatterjee
Department of Printing Engineering
Jadavpur University, Salt Lake Campus
Kolkata – 700098, India

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JADAVPUR UNIVERSITY

Department of Printing Engineering

Certificate of Recommendation

This is to certify that SOURAV SINHA(Exam Roll Number :**M4PRI1605,** Registration Number:**129441of 14-15**) has completed his dissertation entitled, "**HALFTONE BASED APPROACH TOWARDS SHOW-THROUGH REMOVAL OF SCANNED DOCUMENT IMAGES**" under the supervision and guidance of Dr. ARPITAM CHATTERJEE, Assistant Professor, Printing Engineering Department, Jadavpur University, Kolkata. We are satisfied with his work which is being presented for the partial fulfilment of the degree of M.Tech in Printing Engineering and Graphic Communication, Jadavpur University, Kolkata – 700098.

Dr. Arpitam Chatterjee
Assistant Professor
Department of Printing Engineering,
Jadavpur University, Kolkata

Dr. Swati Bandyopadhyay
Head of the Department
Department of Printing Engineering
Jadavpur University, Kolkata.

Dr. Shivaji Bandyopadhyay
DEAN
Faculty of Engineering & Technology
Jadavpur University, Kolkata.

JADAVPUR UNIVERSITY

Faculty of Engineering and Technology

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The thesis at instance is hereby approved as a creditable study of Engineering subject carried out and presented in a manner satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinion expressed or conclusion drawn therein, but approve the thesis for the purpose for which it is submitted.

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Declaration of Originality and Compliance of Academic Ethics

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of the Master of Technology in Printing Engineering and Graphic Communication studies.

All information in this document has been obtained and presented in accordance with academic rules and ethical conduct.

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Name	:SOURAV SINHA
Examination Roll No	:M4PRI1605
Registration No.	:129441 OF 14-15
Thesis Title	:HALFTONE BASED APPROACH TOWARDS SHOW-THROUGH REMOVAL OF SCANNED DOCUMENT IMAGES
Signature with Date	:

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SOURAV SINHA

Class Roll Number :**001411602008**
Exam Roll Number : **M4PRI1605**
Registration Number : **129441** of **14-15**
Masters in Printing Engineering And Graphic Communication
Department Of Printing Engineering,Jadavpur University, Kolkata.

ABSTRACT

Historical documents suffer from different type of degradation and noise such as background variation, uneven illumination or dark spots. Scans of double-sided documents often suffer from show-through distortions, where contents of the reverse side (verso) may appear in the front-side page (recto). It happens due to transparency of the document or ink bleeding. Show-through removal from scanned document image is a challenging problem. There are some standard algorithm like Otsu, Niblack, Sauvola et al and some other method mostly based on those standard methods.

Here a new method based on halftoning is presented. The results are tested using some standard DIBCO document images and it is found that the results are better than those standard algorithms .The method also includes a neighborhood based post-processing step to remove the background noise after the halftoning. The process requires only one side of the document. This halftone based method is fast and it does not require any user input.

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CHAPTER-1

Introduction

1.1. Introduction

In scanned double-sided document image sometimes along with the recto portion's written image the verso portion's written image gets overlapped or vice versa. It is called back-to-front effect or show-through or see-through effect [1]. It happens due to many factors like old paper, poor quality of the paper, limitation of printing process, high transparency of the paper or seeping of the ink of the text printed in the reverse side of the page, etc [2]. To enhance the readability by machine or human the removal of such show-through is required. Such need is considerably increasing in today's digital world where huge number of printed documents to be digitized to meet the requirements. Examples of few such images that are degraded due to show-through problem are shown in Fig.1.1 and Fig.1.2.

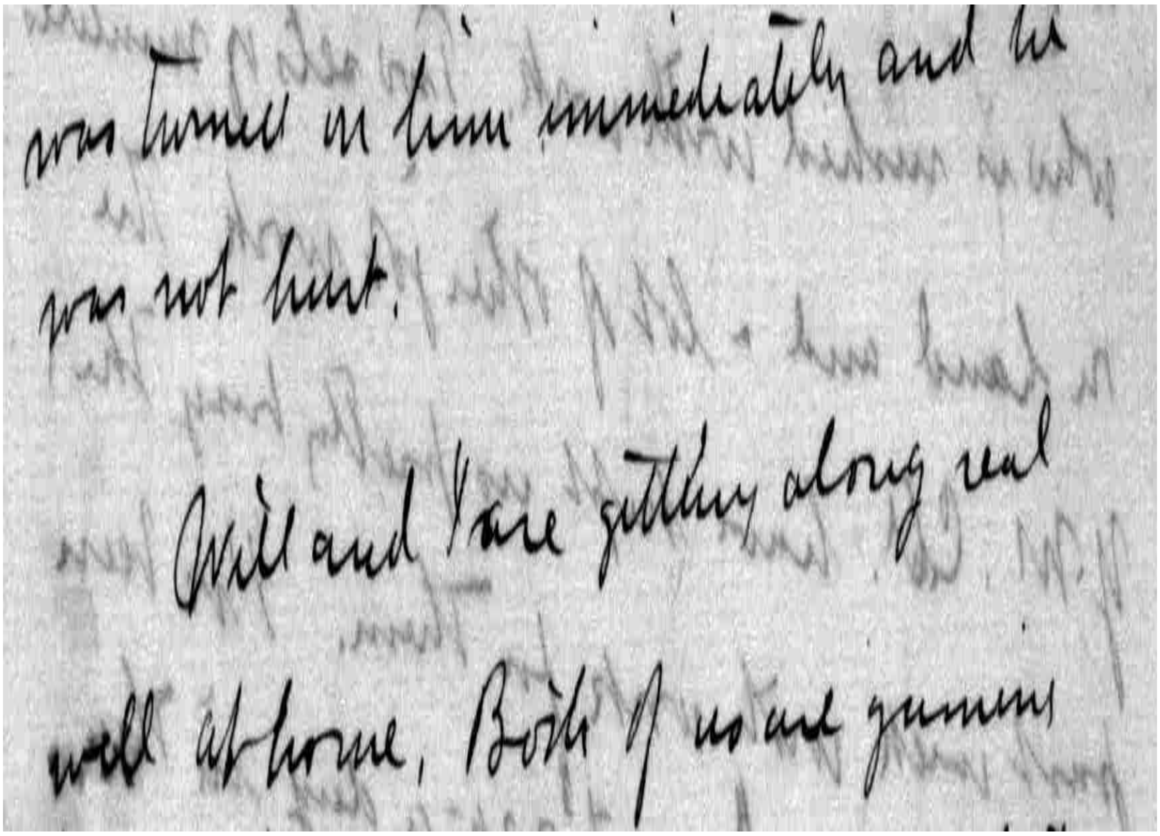
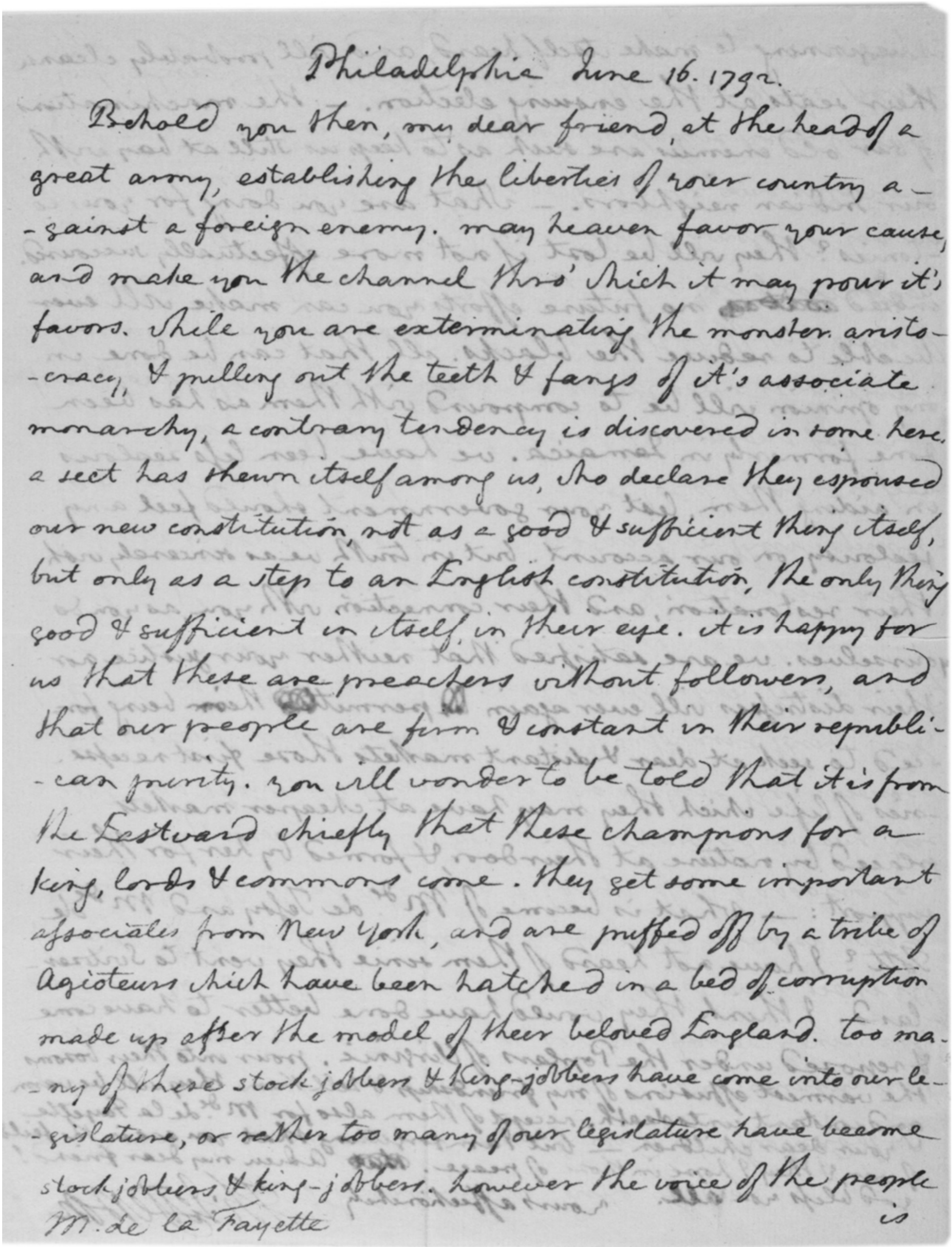

was turned in time immediately and he
was not hurt.
Will and I are getting along real
well at home, Both of us are gaining

Fig.1.1.A typical show-through affected document image



Philadelphia June 16. 1792.

Behold you then, my dear friend, at the head of a great army, establishing the liberties of your country against a foreign enemy. may heaven favor your cause, and make you the channel thro' which it may pour it's favors. while you are exterminating the monster aristocracy, & pulling out the teeth & fangs of it's associate monarchy, a contrary tendency is discovered in some here. a sect has shewn itself among us, who declare they espoused our new constitution, not as a good & sufficient thing itself, but only as a step to an English constitution, the only thing good & sufficient in itself, in their eye. it is happy for us that these are preachers without followers, and that our people are firm & constant in their republican purity. you will wonder to be told that it is from the Eastward chiefly that these champions for a king, lords & commons come. they get some important associates from New York, and are puffed off by a tribe of Agioteurs which have been hatched in a bed of corruption made up after the model of their beloved England. too many of these stock jobbers & King-jobbers have come into our legislature, or rather too many of our legislature have become stock jobbers & king-jobbers. however the voice of the people is

M. de la Fayette

Fig.1.2. Another document image highly affected by show-through.

There are lot of research works going on to address this problem. The literature presented in following section provides a considerable amount of such works. The literature reveals that in most of the cases the standard binarization techniques namely, Otsu , Niblack, Sauvola et al. etc. been used. This chapter draws the possible research direction based on the literature survey presented and frame the thesis objectives.

1.2. Literature survey

There have been many standard algorithms which are proposed to deal with the show-through problem [1-3]. The methods reported in [1 – 3] binarize the documents and get rid of show-through portion. Methods are proposed to scan and match front and rear side of document [4-6]. It removes the show–through components but faithful matching is not always possible. Some method only use one side of the scanned document because in case of old historical document image the verso portion is rarely available and removal of show-through is accomplished by wavelet transform based technique [7]. Some recent methods use Chan-Vese active contour model with energy minimization [8]. In [9] a regularized energy function is defined that uses data term likelihoods and smoothness term Markov Random Field (MRF).

A classification approach is also proposed in [10] where a smoothness term built from a learning set. Also methods which remove the framing borders, segregate the image into blocks and classify the noise into three categories followed by applying different threshold values to each block of the image [11-12] been proposed. Use of model-based techniques are also been reported. In this regard fast algorithms are available based on Independent Component Analysis [13], Fast Correlation [14], etc. Regularization techniques using MRF is used to compensate nonlinearity [15]. A total variation stabilizer based technique [16], a nonlinear model is proposed whose parameters are learned by nonlinear ICA [17], variational approach based on nonlinear diffusion and wavelet transforms [18] are also used.

Some methods [19] propose the restoration of color documents by estimating the background colors and correcting them by multi-scale analysis. However this method seems to have problems when there are large show-through components. In [20] by removing the framing borders image gets divided into blocks and the bleeding noise gets classified into three categories: weak, medium and strong. Different threshold values are applied to each block of the document image. Then they check the presence of blur in the image, and the show -

through pixels are filled using linear interpolations. The performance of the method depends on the accuracy of the noise classifier.

There are some methods which deal with the problem by decomposing the image into a Multi resolution Contrast representation [21] to obtain the contrast of components at different spatial scales. Wavelet based techniques [22] for enhancing the foreground strokes is also used. Compensations for the apparent nonlinearity and non–stationarity of the physical phenomenon have used penalized nonnegative matrix factorization (NMF) [23].

In [24] and [25] this model is used for bleed-through as well employing a constrained maximum likelihood technique for blindly estimating both the mixing parameters and the source images, or estimating off-line the model parameters. Several thresholding techniques [26] are compared for separating text and background in degraded, historical documents, and the result is that neither global nor local thresholding can perform satisfactorily.

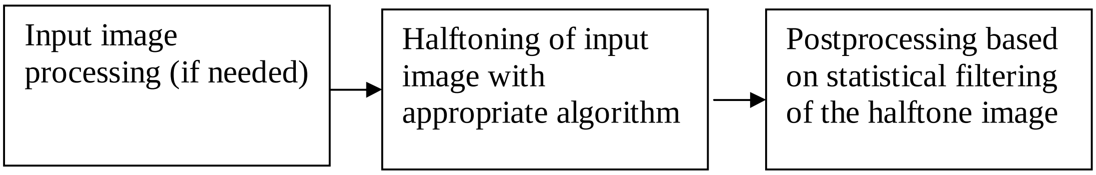
In [27] segmentation and grouping techniques based on the Gestalt cognitive rules from the visual system behaviour are used to eliminate interfering strokes from skeletonised versions of handwritten documents. In [28] local adaptive filters also based on evolutionary algorithms are applied for homogeneous and textured background removal still from handwritten gray-level documents. For show- through problem some work has been done mainly based on the exploitation of information from the front and back pages. In [29] a wavelet technique is applied for iteratively enhancing the foreground strokes and smearing the interfering strokes. In all these methods a preliminary registration of the two sides is required. In [30] a Fast ICA algorithm which is fully blind and extremely fast procedure is used.

1.3. Scope of the thesis

The major scope of the thesis can be drawn as follows:

> **For show-through removal problem all the major work mainly depends on Otsu [31], Niblack [32], or Sauvola et al [33] algorithms. Hence a new technique based on halftoning is explored since halftoning can retain the visual information of tonal gradations in binary form and can have possibility towards better segmentation of text and background.**

In this thesis work we present a digital halftoning based show-through removal technique. The digital halftoning [34] is conventionally used for reproduction of continuous tone images with lesser number of tones available with output devices and its application is majorly restricted to print media. The main motivation of using halftoning is its ability towards good quality binarization retaining the tonal variation instead of hard thresholding based binarization. The study involves an investigation towards replacing conventional established binarization techniques e.g. Otsu [31], Niblack [32], Sauvola et al [33] etc by halftoning techniques for subjected problem. The presented method was tested with different test images and found to be potential considering its simplicity and fast processing. The probable implementation method can be presented as following diagram.



Historical old age document suffers from different types of degradation such as background variation, uneven illumination or dark spots. In case of double-sided documents another common problem is that the back side of the document interferes with the front side because of the transparency of the document or ink bleeding. This effect is called show-through phenomenon. Many methods are developed to solve these problems and it requires both front and back side of the document where they scan and match both side of the document. In contrast here in this thesis a new algorithm is used which is halftone based and it does not require both side of the page. Here only one side of the scanned document is used. We hypothesize that show-through are low–contrast components and foreground components are high contrast ones.

1.4. Chapter-wise outline

Chapter1: This chapter provides brief introduction of the mentioned problem. Here a gist about what is show- through problem has also been mentioned. All the major works in this field are followed by a literature survey. The chapter elucidates scope of the thesis and a chapter wise overview of the thesis.

Chapter2: The second chapter deals with established binarization processes. Here first what is document image and its utilities are discussed. After that the thresholding standard techniques are discussed. By means of thresholding techniques we binarize a document image. Here global and adaptive thresholding are discussed briefly. How we choose a particular thresholding method is also discussed here. All the major binarization methods like Otsu, Niblack, and Sauvola et al etc are also mentioned here. A method based on Parker is also discussed step by step. Applying all the standard algorithms the output binarized versions of the images are also shown there.

Chapter3: Digital halftoning techniques have been discussed here. Firstly what is halftoning is discussed. When it is used is also mentioned here. There are mainly three classes of halftoning techniques. Those are Point processing, neighbourhood processing, iterative techniques. All are discussed here.Error Diffusion is an important approach in neighbourhood processing .Its advantages and disadvantages are mentioned here. Later dispersed dot ordered dithering and clustered dot ordered dithering are discussed. Lastly the chapter is concluded by discussing a brief about Error Diffusion. All the algorithm are run on two show-through affected DIBCO test images and it is found that after applying error-diffusion algorithm the output images are quite good candidate for post processing step.

Chapter4: This chapter presents post-processing steps after halftoning. Here order statistics filters are used. The mean, median, maximum, minimum and one more rank order filter based on median filter are used. Among the filters mean, median and the new rank order filter show good results with recognizable pure binary images. One comparative study based on all existing algorithms like Otsu, Sauvola et al, Niblack with the new algorithm used in this thesis are also discussed here.

Chapter5: The final chapter accumulates all the major findings of the thesis. It summarizes the concluding remarks and the plausible future extensions of the work.

1.5. Conclusion

Show- through are one of the major problems in document images. Previously the standard algorithm like Otsu, Niblack, Sauvola et al are mostly used to get rid of it. But here in this thesis a new algorithm based on halftoning is used. This method also includes a neighbourhood based post-processing step.

1.6. References

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CHAPTER-2

Standard Binarization Methods

2.1. Introduction

Nowadays internet access makes document collections easy. This digitization process depends heavily on (OCR) technique and for that we need a binarized version of the image. The reason is OCR technique performs better when provided with pure black and white image. In 1979 Otsu [1] proposed a simple but effective algorithm for binarization purpose. It is based on optimal clustering. It is a global thresholding method. In global thresholding we have one threshold value for entire image based on which we segment the image. Here darker pixels are set to black and lighter pixels are set to white.

Niblack [2] proposed an algorithm which depends on adaptive thresholding technique. Here local pixels are considered and different threshold values are set for different regions. This method gives better output on some images and worse output in other. Sauvola [3] proposed an extension of Niblack to overcome the problem faced by Niblack.

Apart from these early binarization methods there are also some significant work on this field. Gatos.et al [4] improved on [3].There is also some method based on Markov random fields [5-7]. One of them amongst [5] won at DIBCO 2011 competition.

Some work depends on foreground and background separation [8] and background estimation [9]. The method [9] placed 2nd in DIBCO 2011 competition.

Some machine-learning based approach [10], [11] is also there. This methods deal with images that are “document-like”. Like [12] extract information for engraved cemetery headstones [13] enhances picture of white boards and [14] extracts data from census tables.

The image binarization process presented here is based on Parker et al [15].The method based on two principles that (1) writing should be darker than nearby non-writing portion (2) writing should also generate significant detectable edge.

2.2. Implementation of established techniques

2.2.1. Otsu's method: The method is based on global thresholding. Here based on one single threshold value we segregate the image into foreground and background. It is a approach based on non-parametric techniques. Here first between class variance and within class variance are calculated. The ratio of this variance has to be maximum. Two different classes are foreground (here text) and background (here non-text) pixels. The aim is to get the threshold value that maximises the variance of intensities between the two classes and minimizes it for within a particular class.

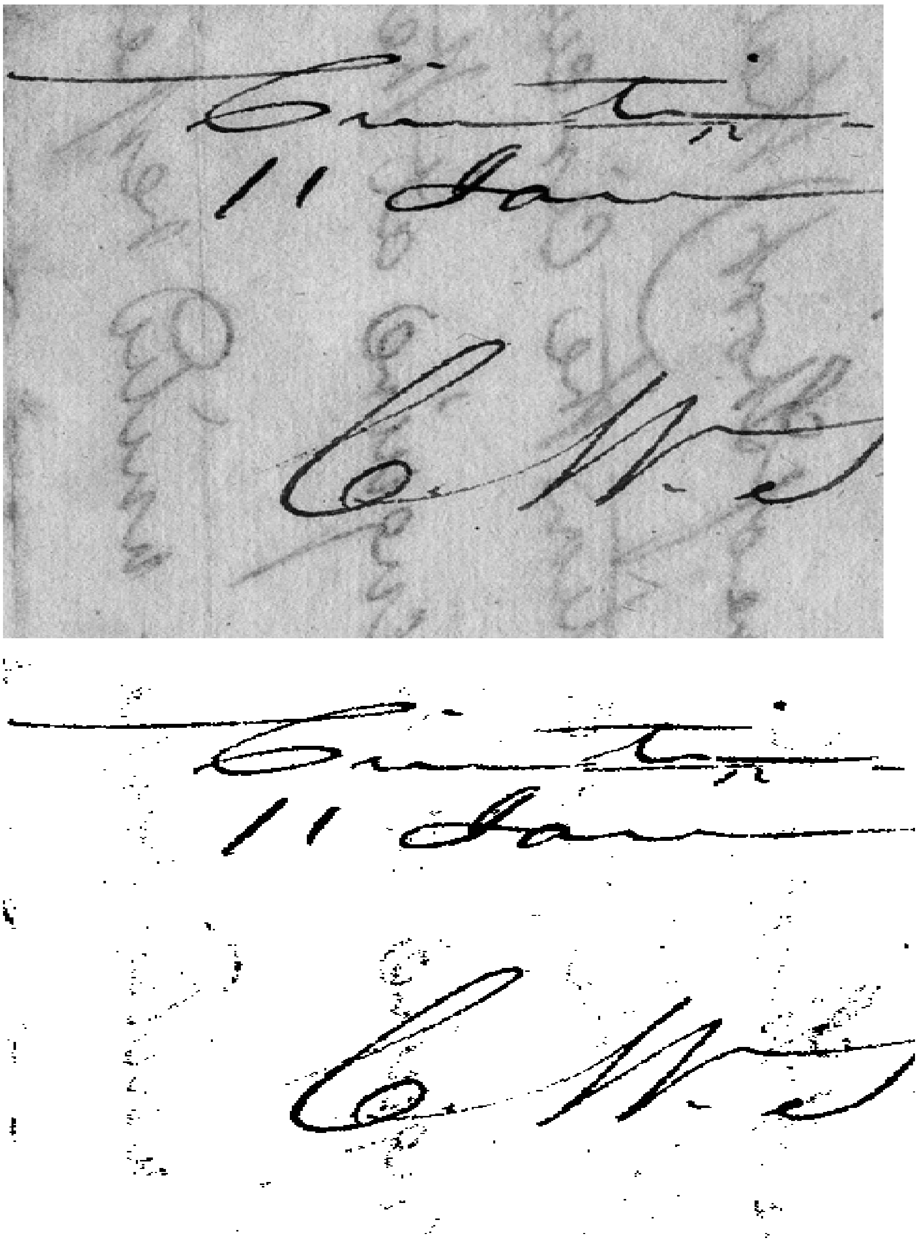

Fig.2.1. A typical binary image after applying Otsu's algorithm (image taken from DIBCO database)

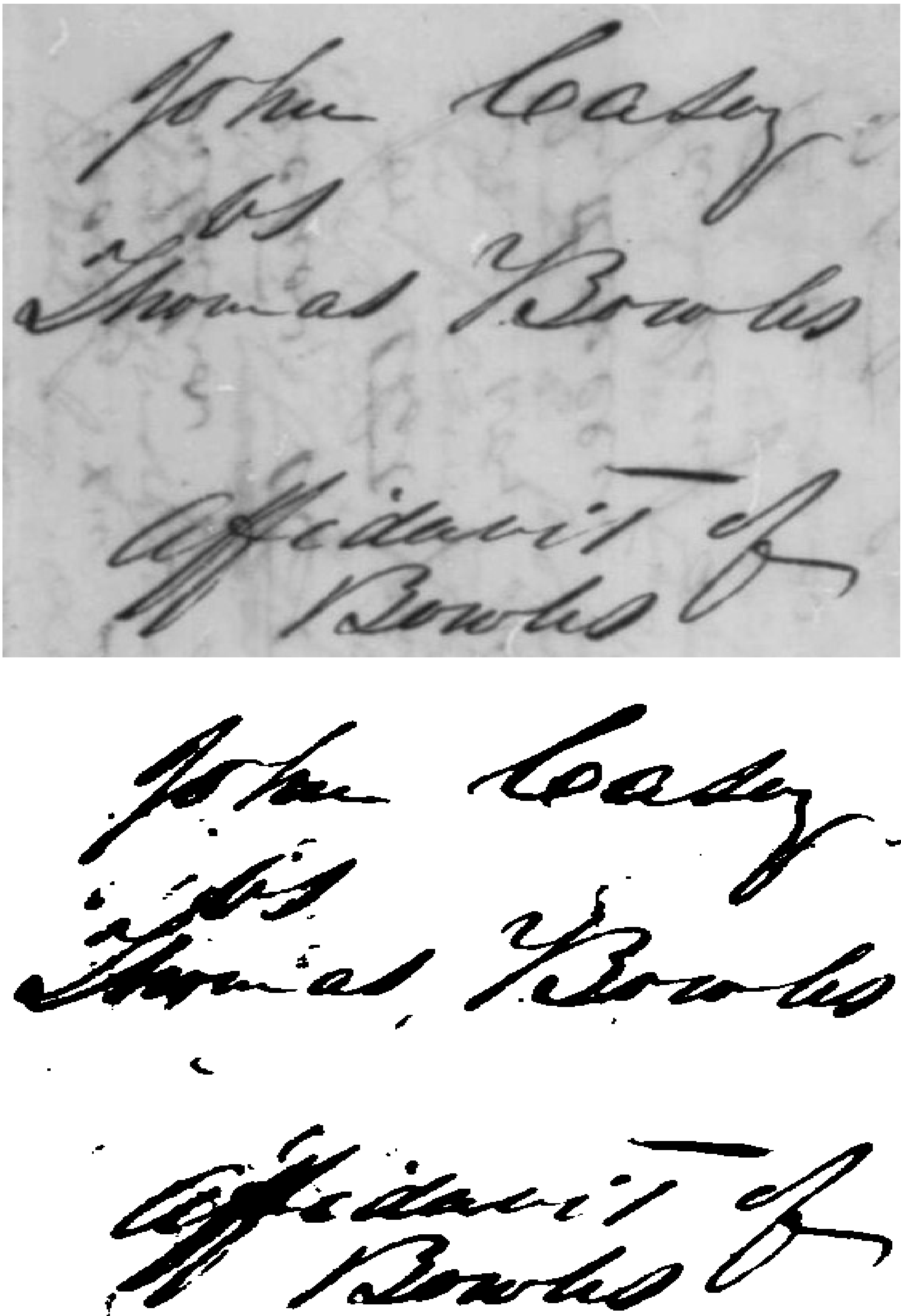

Fig.2.2. Another typical binary image after applying Otsu's algorithm (image taken from DIBCO database 2009).

2.2.2. Niblack's Technique: It is a technique based on adaptive thresholding. The image will have different threshold values for different region. Niblack's algorithm [2] calculates a pixel-wise threshold by sliding a rectangular window over the gray level image. The computation of threshold is based on the local mean m and the standard deviation's of all the pixels in the window and is given by the equation below:

$$T = m + k * s$$
$$T = m + k\sqrt{(1/NP)\sum (p-m)^2}$$
$$= m + k\sqrt{\sum (p^2)/NP - m^2}$$

Where *NP* is the number of pixels in the gray image, *m* is the average value of the pixels p, and *k* is fixed to -0.2 by the authors. T is the Niblack's threshold value.

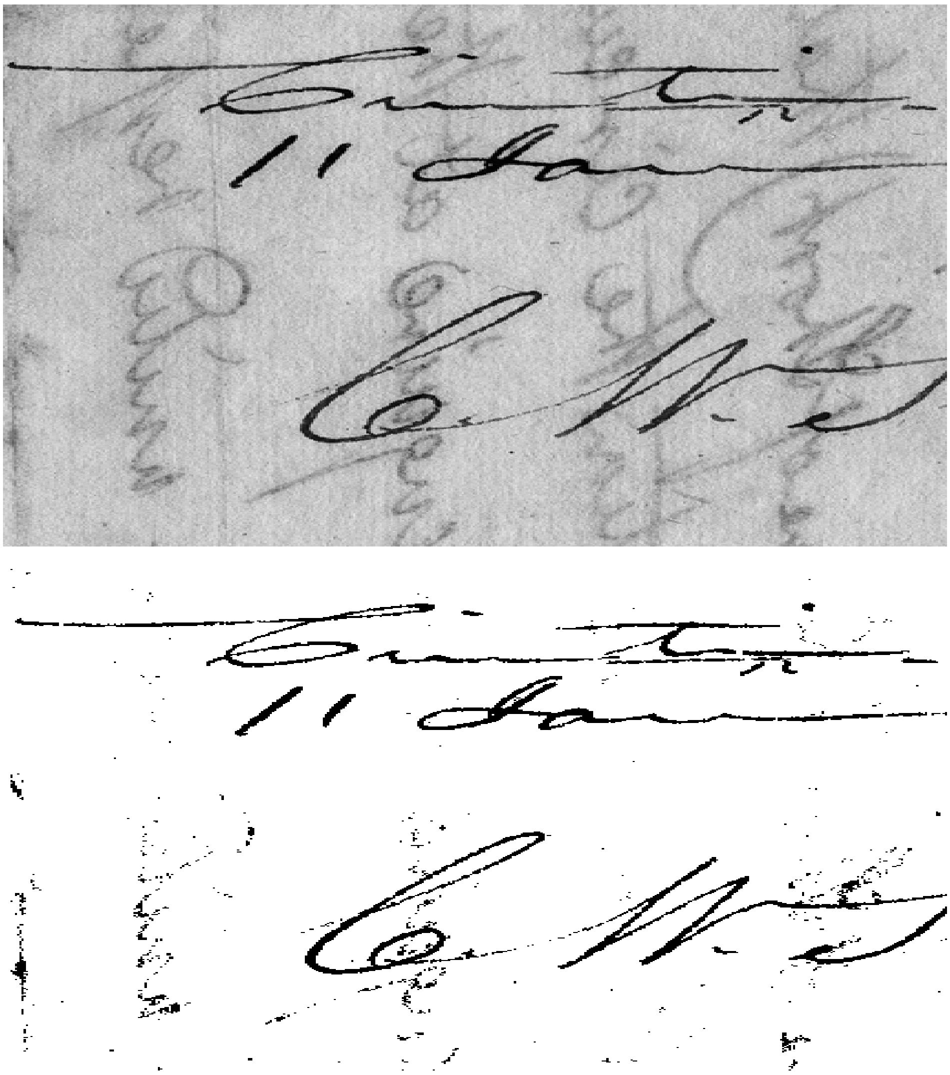

Fig.2.3. A typical binary image after applying Niblack's algorithm (image taken from DIBCO database)

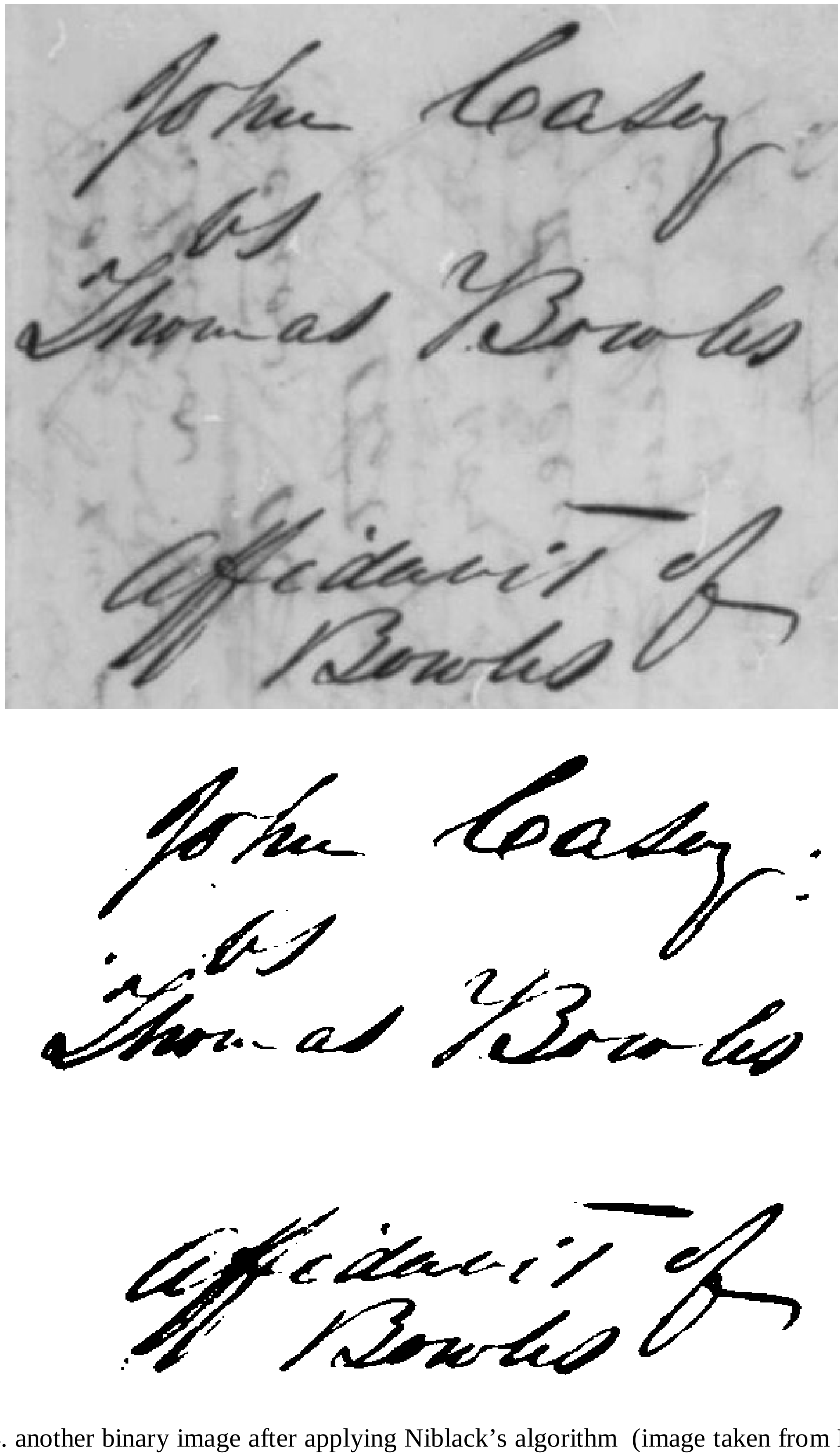

Fig.2.4. another binary image after applying Niblack’s algorithm (image taken from DIBCO database 2009).

2.2.3. Sauvola's method: Sauvola's algorithm [3] claims to improve Niblack's method by computing the threshold using the dynamic range of image gray-value standard deviation, R

$$T=m*(1-k*(1-S/R))$$

Where k is set to 0.5 and R to 128.Here T is the Sauvola threshold value.

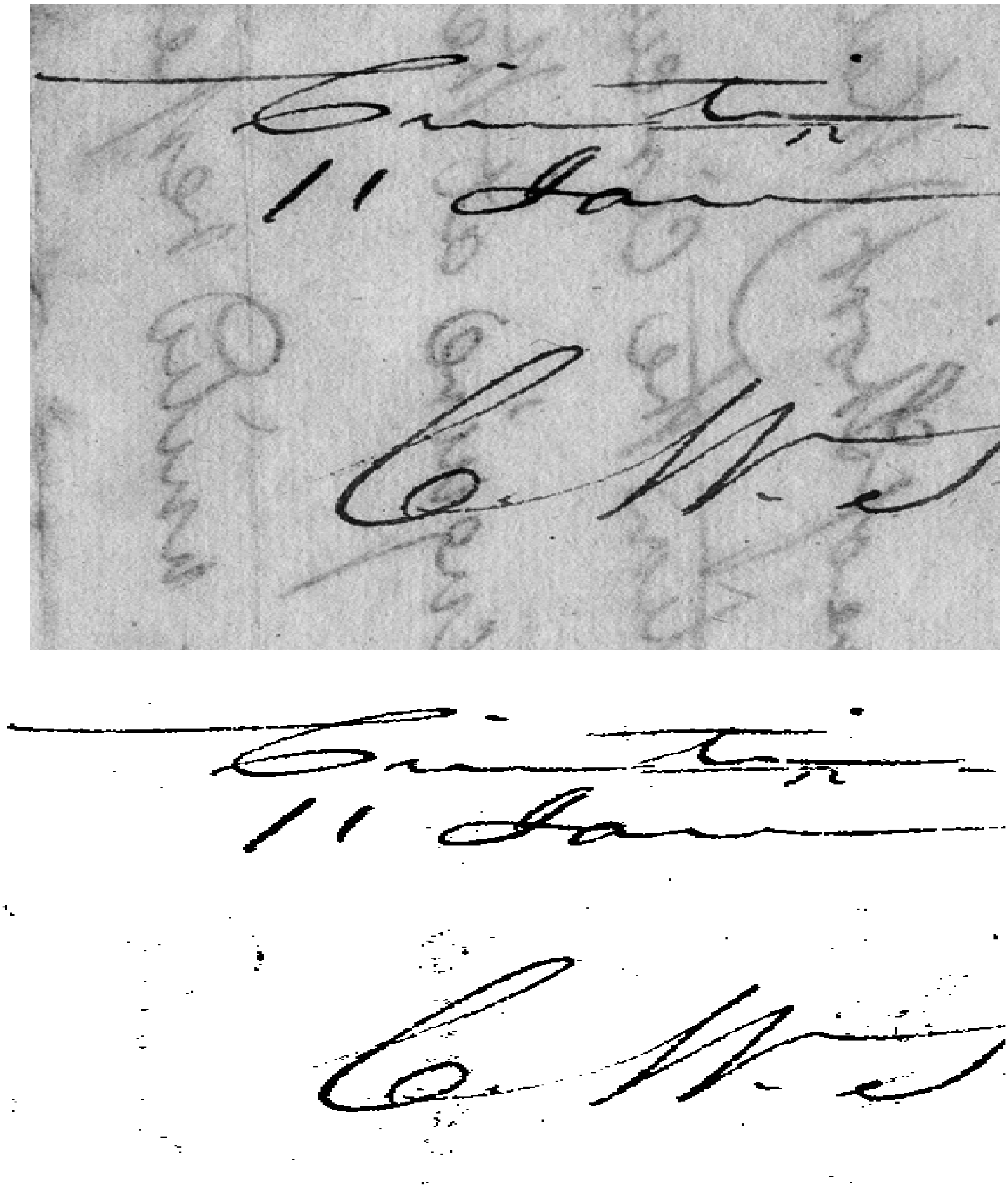

Fig.2.5.A typical binary image after applying Sauvola's algorithm (image taken from DIBCO database).

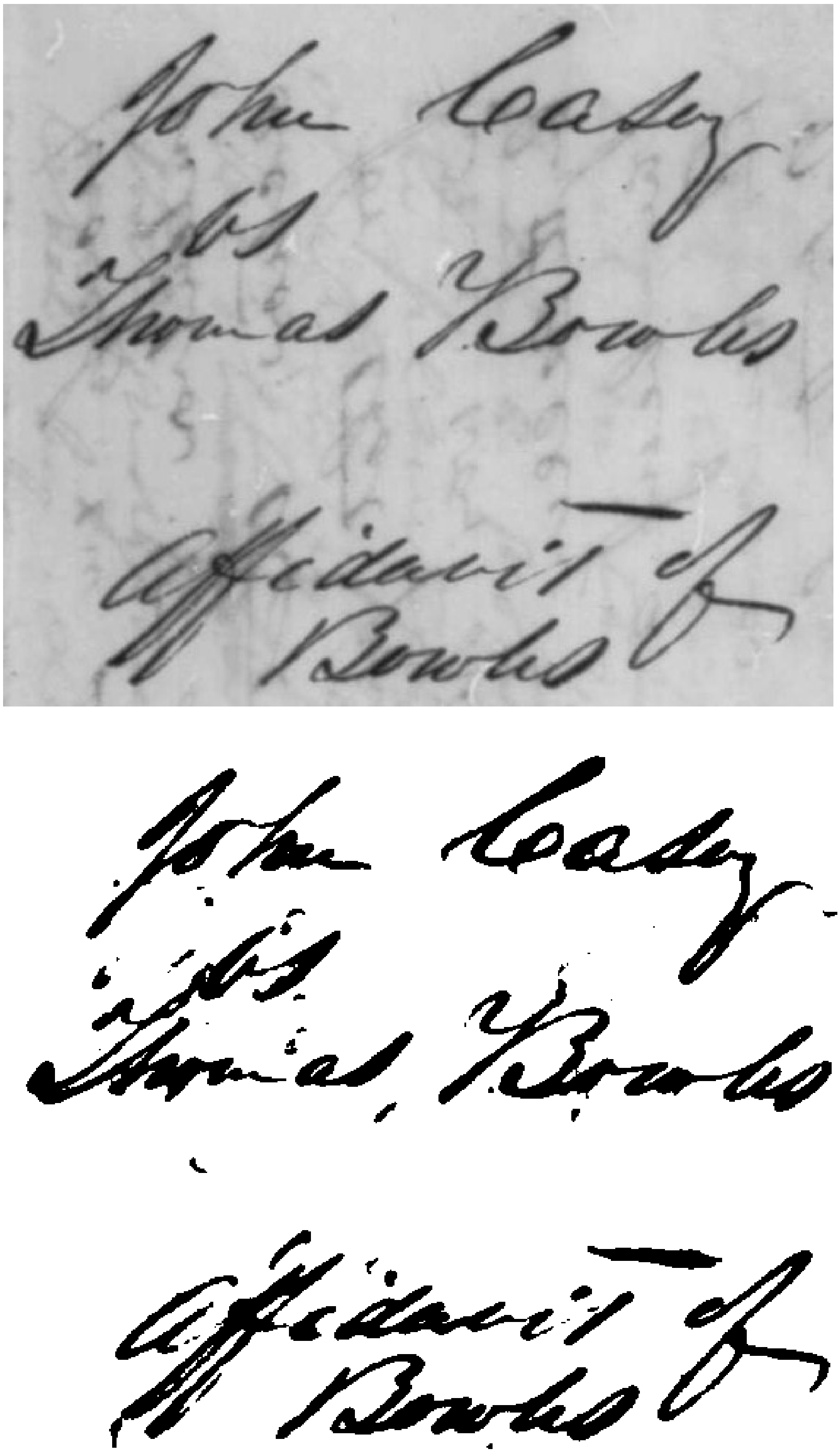

Fig.2.6. A typical binary image after applying Sauvola's algorithm (image taken from DIBCO database 2009).

2.2.4. Method based on Parker et al.

Creating a greyscale image: First the image must be converted to grayscale image from input color image (Fig-2.7.). Here PCA (principle component analysis) is used to convert the input color image (which can be considered as 3-dimentional image) to output greyscale image (which can be considered as 1-dimentioal image).We don’t require the step if input is already a grayscale image.

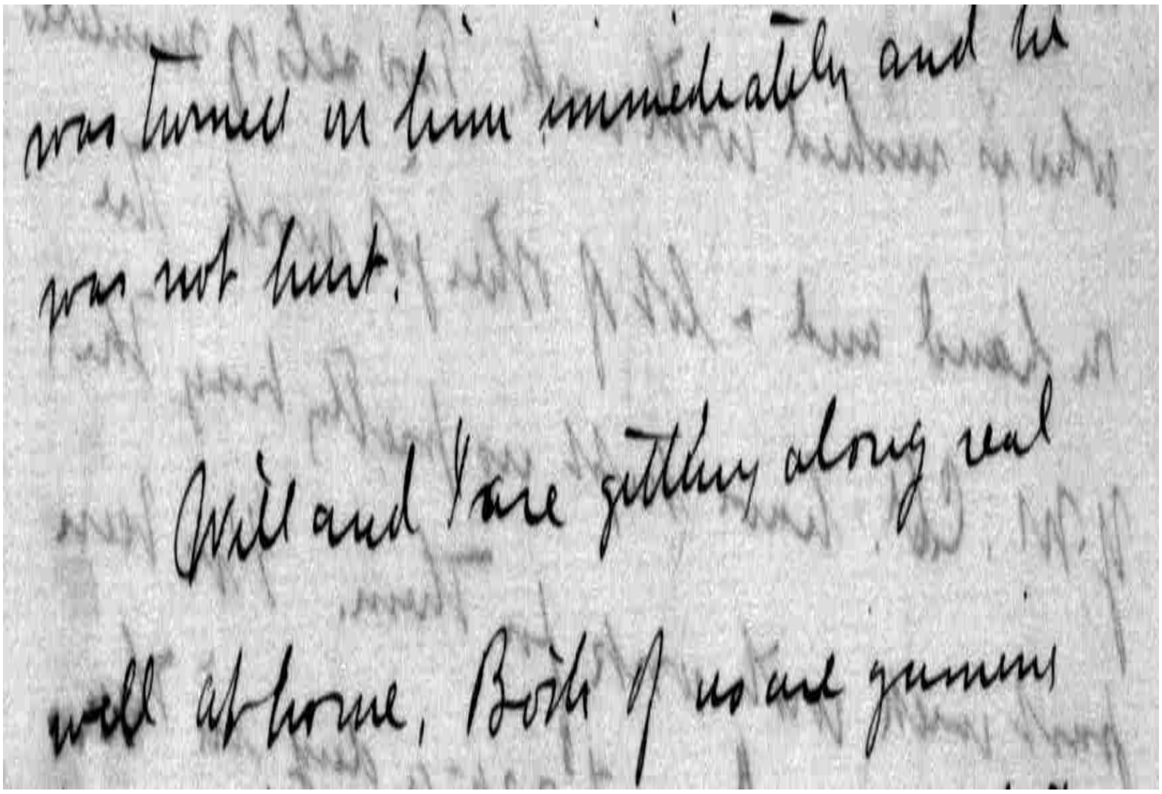
was turned in time immediately and he
was not hurt.
Will and I are getting along real
well at home, Both of us are

Fig.2.7. A typical gray scale version of show-through document image

Identifing locally dark pixels:

Identifying locally dark pixels is the first step using the grayscale image as input. Each pixel in the image is analyzed separately by applying Otsu’s method to a snippet of local pixels from the grayscale image. A pixel is added to the set of “locally dark” pixels if the pixel is set to black when Otsu’s method is applied to its corresponding snippet of local pixels. If the pixel is to be black in the final output image (fig-2.8) it must be identified as “locally dark” in this step .In fig-2.8 the typical output of the step is shown. This filter generates a sharp outline of the text in the image. But this filter is ineffective when applied to background. When the filter is applied to background it only highlights the noise from the grayscale image. Next section introduces another filter which when intersects with this clarifies the background portion of the image.

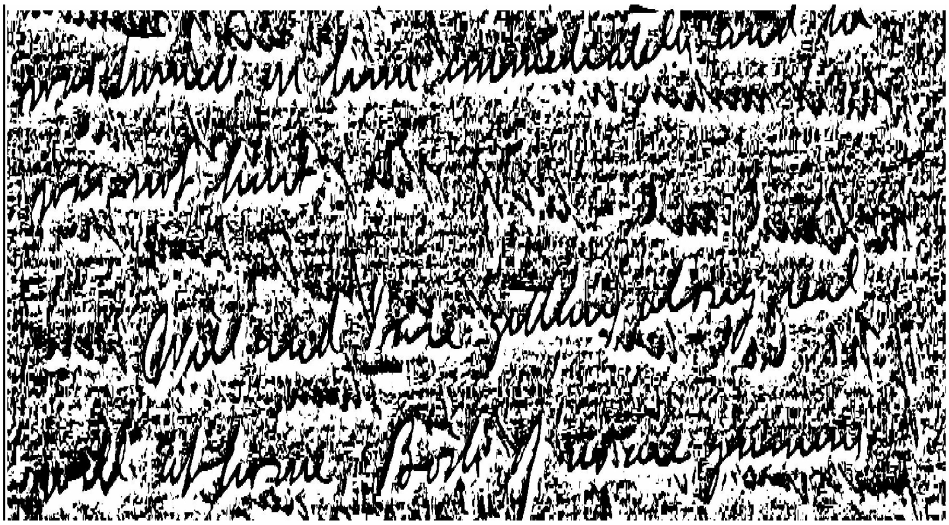

Fig.2.8. Image containing locally dark pixels

Edge pixel identification:

First the pixels which are near the edge are identified. For that the Sobel edge detector is used. The Sobel edge detectors are run on the grayscale image. The image produced by the Sobel operator is then gently smoothed using Gaussian filter. It minimises the effect of image noise. Next the standard deviation of the grayscale values found in each snippet of local pixels extracted from the smoothed edge detection image is computed. These standard deviations are then normalised so that they range from 0 -255.On this grayscale image the Otsu’s method is applied. It identifies regions that are near an edge. The result is shown in fig-2.9,fig-2.10,fig-2.11.

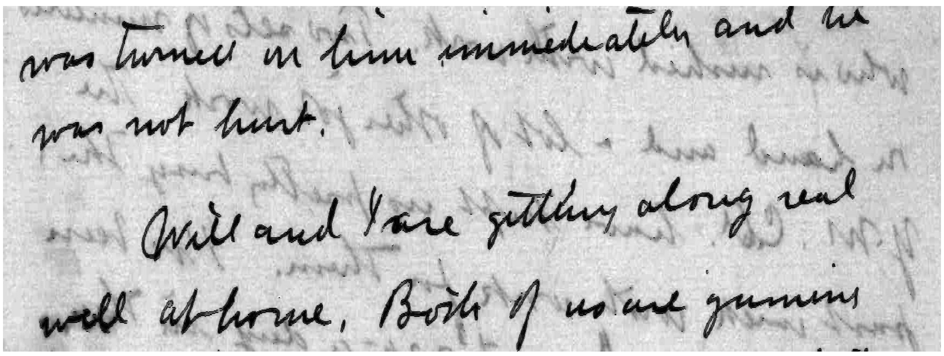

Fig.2.9. A typical result from applying edge detection (Sobel)

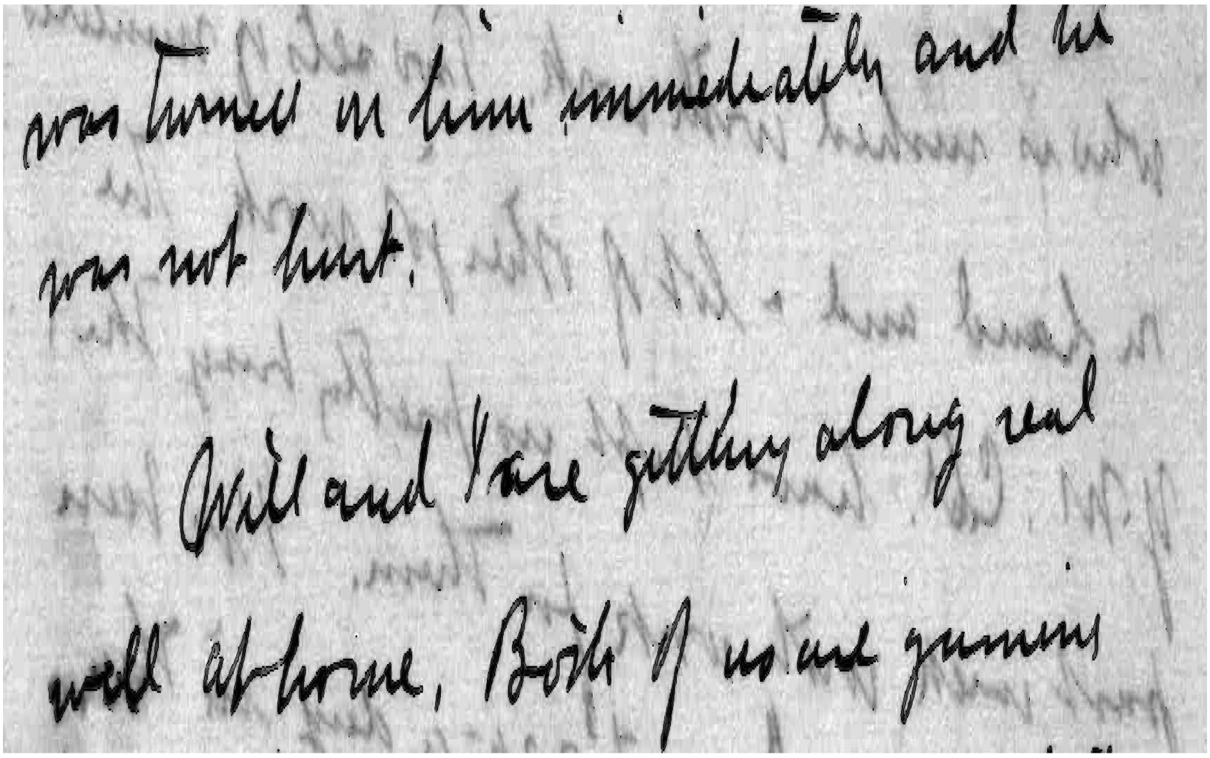

Fig.2.10. Smoothen   image

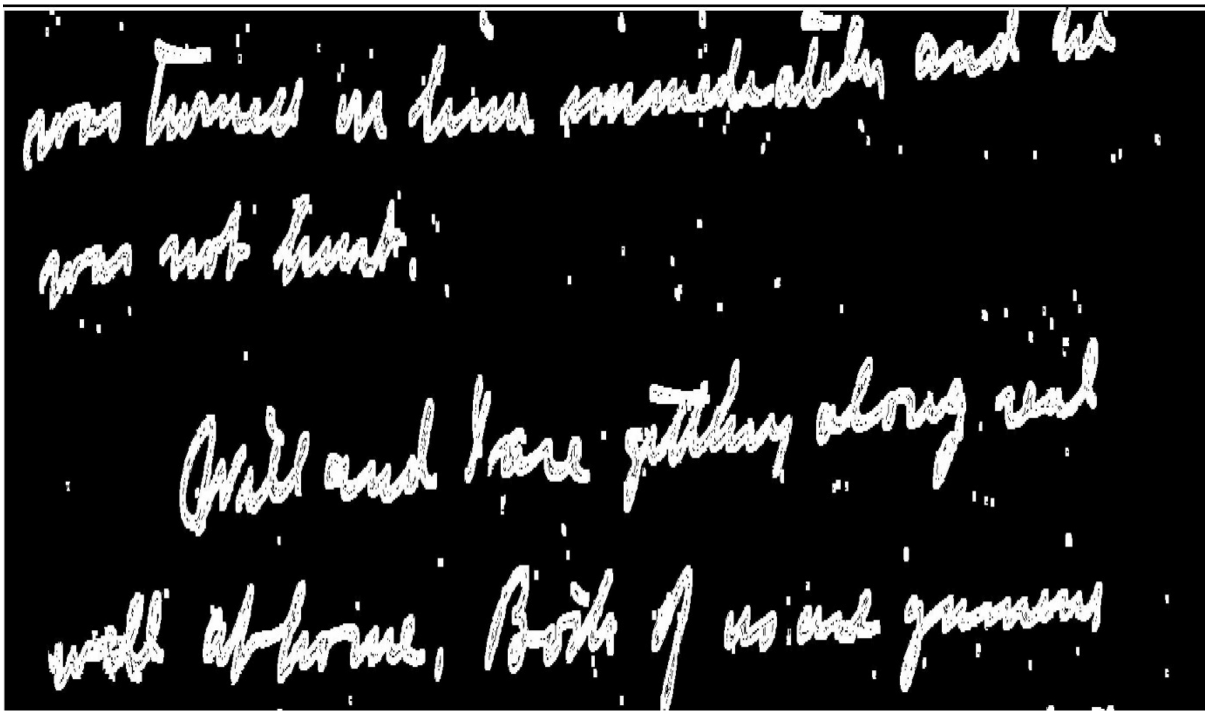

Fig.2.11. Computing standard deviation of local grayscale values and applying Otsu's method

The intersection computation:

The results from identifying locally dark pixels and pixels that are near an edge can be seen as two filters .The intersection of these filters generates a distinctly good black and white image (fig-2.12) provided the snippets used to compute the standard deviations of local grayscale values are smaller than the snippets used to identify locally dark pixels.

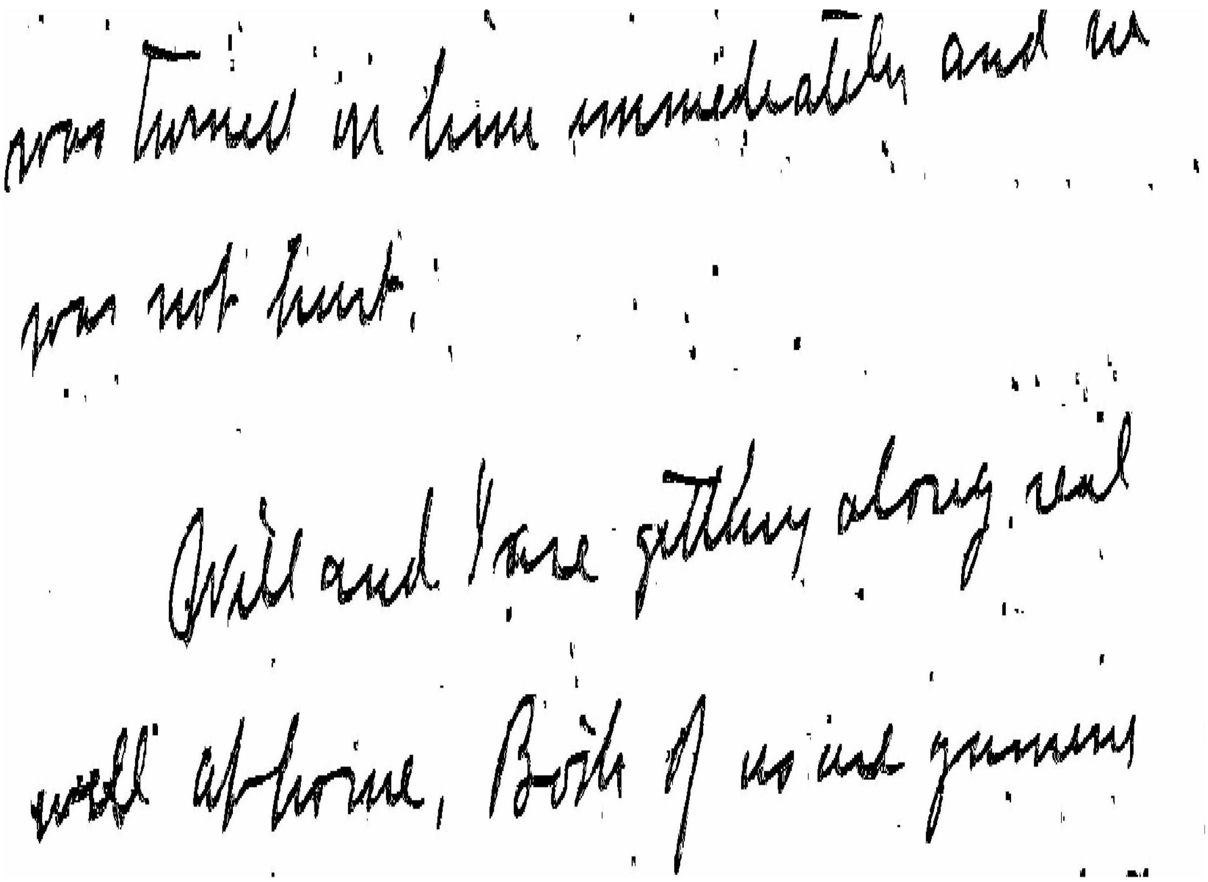

Fig.2.12. The output intersection of locally dark pixels identified in section 2.2 and the pixels that are near an edge identified in section 2.3.

2.5. Conclusion

Among the distinguished binarization methods image got from Otsu's algorithm still have some significant amount of noise in the background. Advantage of Niblack is that it always identifies the text regions correctly as foreground like in the two images shown above but on the other hand tends to produce a large amount of noise in non-text regions also. Sauvola method outperforms Niblack's algorithm in images where the text pixels have near 0 gray-value and the background pixels have near 255 gray-values. However, in images where the gray values of text and non-text pixels are close to each other, the results degrade significantly. In the images shown above using Niblack's method the text which is extracted from background is very prominent and noise is also significantly reduced over there. Lastly the method based on Parker is also capable of extraction of text from show-through affected images.

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CHAPTER- 3

Digital Halftoning

3.1. Introduction

Halftoning is the process of transforming an image with greater amplitude resolution to one with lesser amplitude resolution. This has been practiced for over a hundred years in the printing industry. the solution for displaying continuous tone images with only black or white dots. A Gray scale digital halftoning is a process to produce bi-level image from continuous tone image. Here in bi-level 0 means black and 1 means white. Although it was invented for printing continuous tone images it is popularly used for electronic displays and output devices as well. Electronic displays and output devices such as printers, LCD displays, plasma panels, etc. which are also limited by its number of reproducible tones also need this technique. However, in digital domain this is commonly referred as dithering. Examples of some halftone images are shown in Fig.3.1.

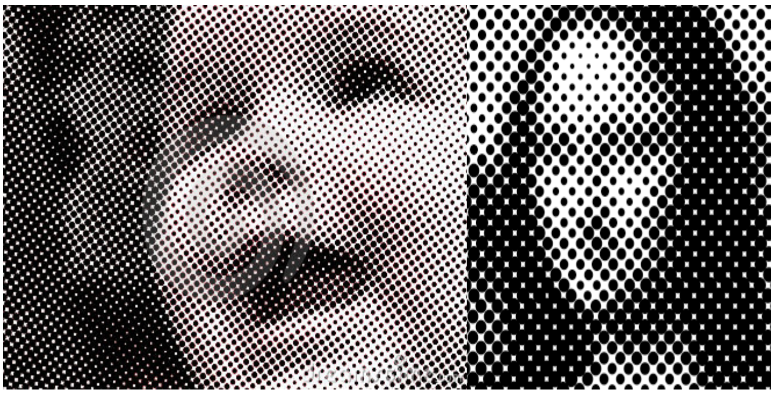


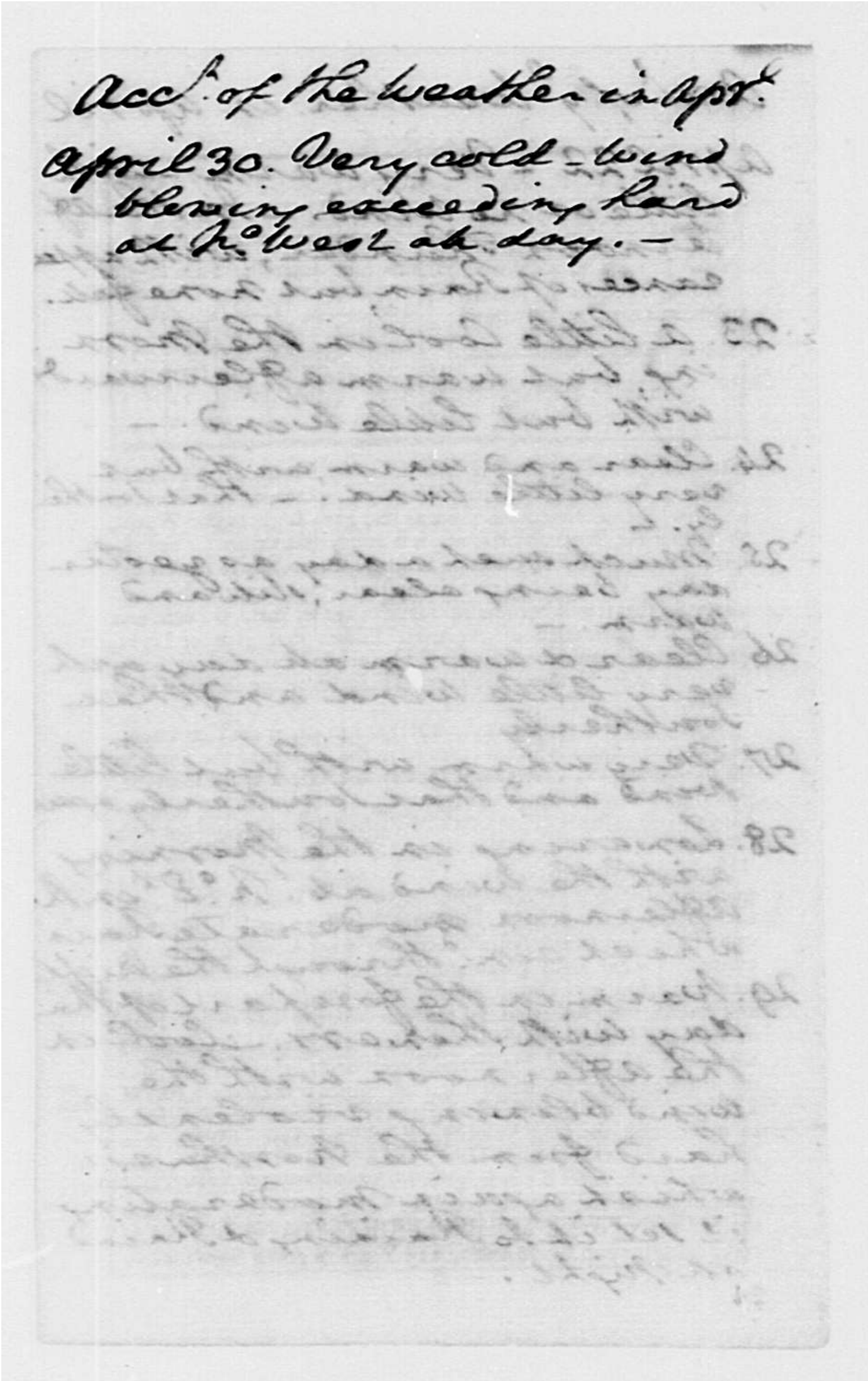
Fig.3.1**.** Examples of printed halftone images

There are mainly three classes of halftoning techniques- point processing, neighbourhood processing and iterative techniques. In point processing individual pixel of the original continuous tone image gets processed whereas in neighbourhood processing needs neighbour pixel information. A comparatively new approach towards halftoning is iterative techniques that give comparatively better results with higher computational complexity and sacrificing processing time.

This chapter provides a brief overview of different popular halftoning techniques and their results with the document images. The detailed analysis of halftone images provided in this chapter shows that the halftoning can be a possible alternative to the standard binarization techniques i.e. Otsu, Niblack, Sauvola et al, etc. for tasks like document image binarization and show through cancellation.

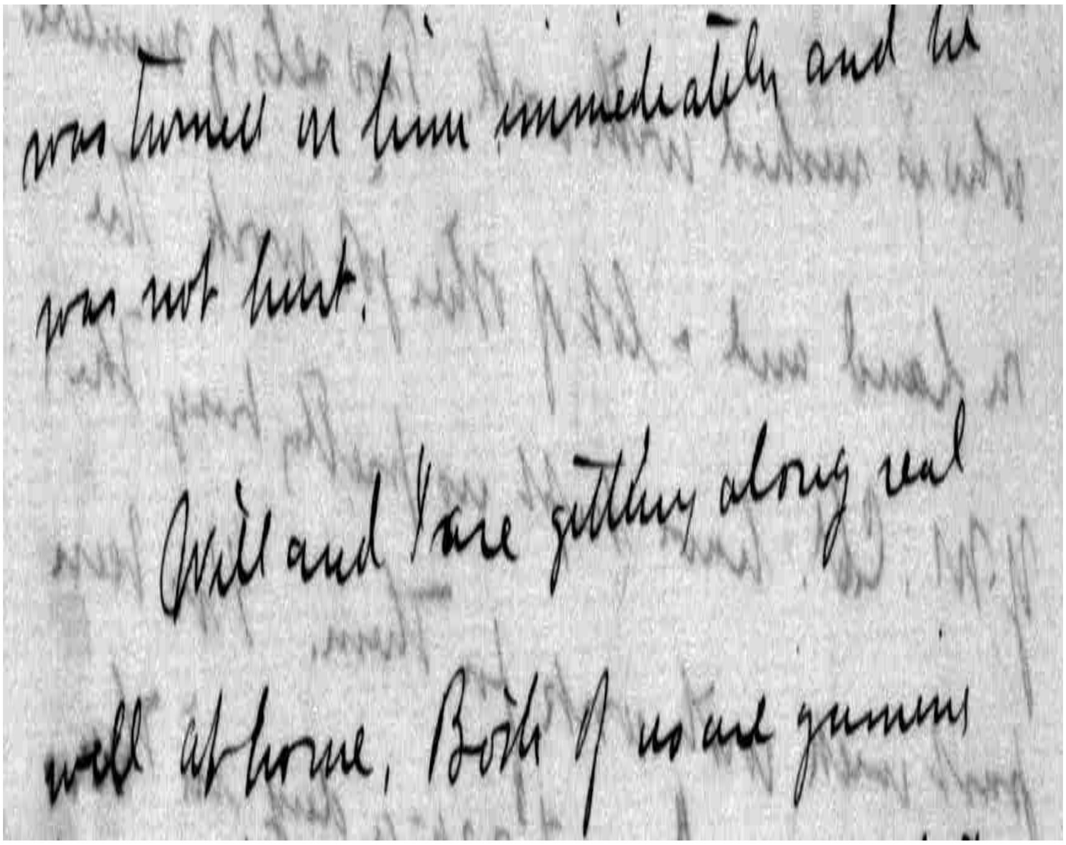
3.2. Brief survey of popular halftoning techniques

This section provides a brief overview of the standard halftoning algorithms. The results of such algorithms are also been demonstrated with the following two document images from standard DIBCO 2009 Test images handwritten and 2010 Test images which suffers from show-through bleed through problems. As it can be easily seen from Fig.3.2 that in both the document images the characters from the reverse side of the page are appearing and creating disturbing patterns.



Acct. of the weather in Apr.
April 30. Very cold – wind
blowing exceeding hard
at No. West all day. –

Fig.3.2. Examples of show-through affected images (from DIBCO2009 Test images handwritten)



was turned in time immediately and he
was not hurt.
Will and I are getting along real
well at home, Both of us and

Fig.3.3. Examples of show-through affected images (from DIBCO test images 2010)

3.2.1. Point processing techniques:

Ordered dithering: It is an image dithering algorithm. It is commonly used by programs that need to provide continuous image of higher colors on a display of less color depth. For example Microsoft windows use it in 16-color graphics modes. It is easily distinguished by its noticeable crosshatch patterns.

The algorithm achieves dithering by applying a threshold map on the pixels displayed causing some of the pixels to be rendered at a different color, depending on how far in between the color is of available color entries.

Ordered dithering have some advantages like the computation is less complex ,implementation is easy, it is much faster and its substantial parallelism. It also have some disadvantages like visually objectionable periodic patterns, low frequency noise, false contouring, it sometimes provides an artificial synthesized image appearance.

Clustered dot ordered dithering : Here the screen matrix follows the analogue halftoning. The halftone dot grows around the pixel as the intensity approaches to black and vice-versa. Here the target spectral characteristics are green noise. Holladay [13] and kang [24] are some of the important development in this regard.

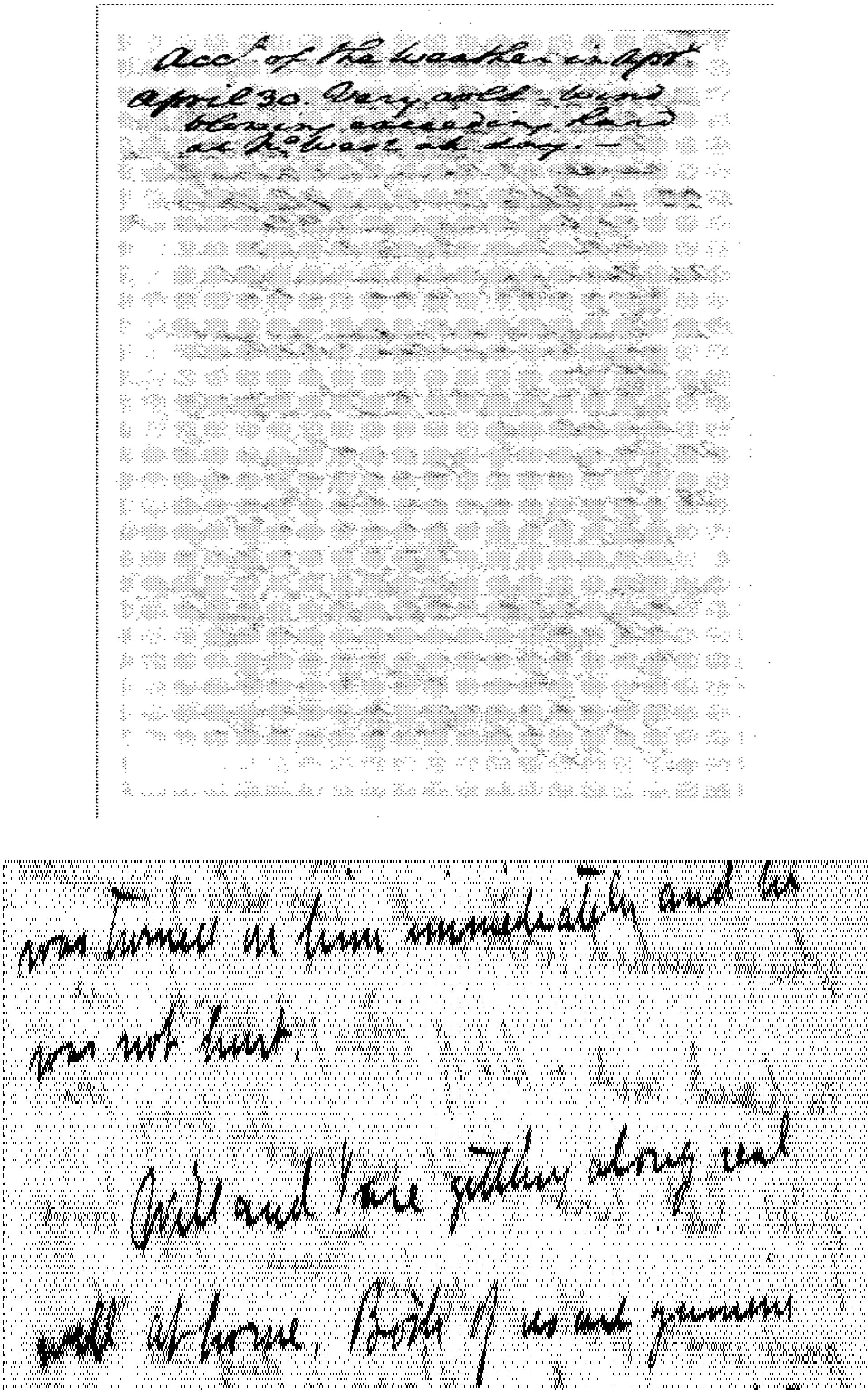


Fig.3.4. Examples of CDOD halftoning

Dispersed dot ordered dithering:

Here the input image is compared with a periodic screen image. The screen image is called screen matrix or threshold array. It defines the order by which the dots are added to the lattice as brightness is increased. Here the target spectral characteristics are blue noise. Bayer [22] and Judic et al [5] are some of the major development in this regard.

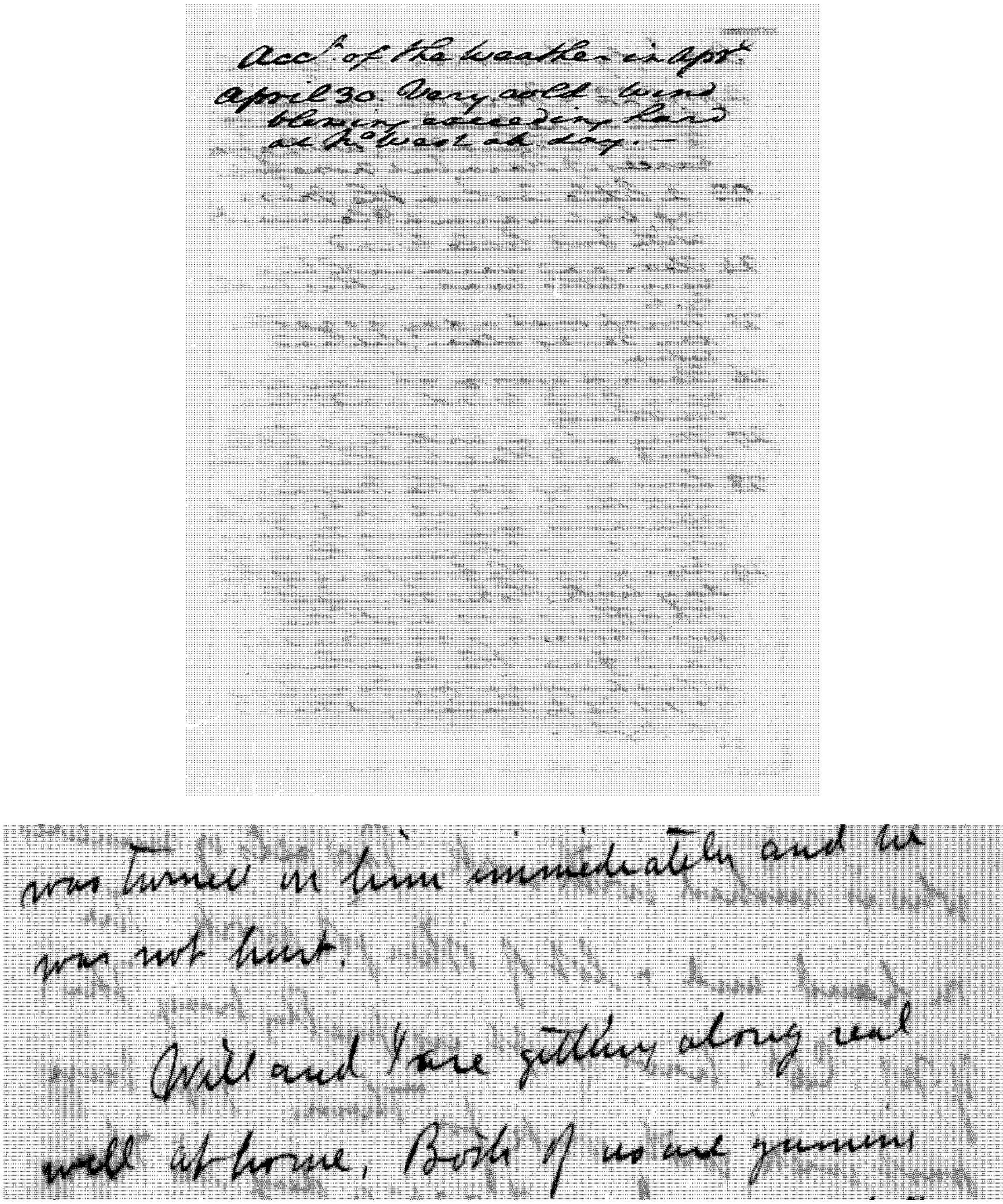


Fig.3.5. Examples of DDOD halftoning

3.2.2. Neighborhood techniques:

In this class the error accumulated during processing a single pixel is distributed to its neighbour in an weighted fashion. This has been the most popular algorithm for a long time and still used in many practical implementations since it provides smooth transitions between different tonal levels.

Error Diffusion:During processing of each pixel an error is accumulated .That error is diffused to its neighboring pixels in an weighted manner. The last step is halftoning by a threshold operation. Here the target area is blue noise. Here Floyd and Steinberg [15], Jarvice et al[16], Stucki [17] are some of the major developments.

Error Diffusion have some advantages like its smooth transition from one level to another provides improved halftone patterns and it provides much satisfactory noise profile. It also has some disadvantages here correlated artifacts specially seen in constant gray regions , here directional hysteresis forms worm-like structure in highlight and shadow regions, it causes lack of sharpness specially at edges in its general form.

One-dimensional error diffusion

The simplest form of the algorithm scans the image one row at a time and one pixel at a time. The current pixel is compared to a half-gray value. If it is above the value a white pixel is generated in the resulting image. If the pixel is below the half way brightness, a black pixel is generated. The generated pixel is either full bright, or full black, so there is an error in the image. The error is then added to the next pixel in the image and the process repeats**.**

Two-dimensional error diffusion

One dimensional error diffusion tends to have severe image artifacts that show up as distinct vertical lines. Two dimensional error diffusion reduces the visual artifacts. The simplest algorithm is exactly like one dimensional error diffusion, except half the error is added to the next pixel, and one quarter of the error is added to the pixel on the next line below, and one quarter of the error is added to the pixel on the next line below and one pixel forward.

Color error diffusion

The same algorithms may be applied to each of the red, green, and blue (or cyan, magenta, yellow, black) channels of a color image to achieve a color effect on printers such as color laser printers that can only print single color values.

However, better visual results may be obtained by first converting the color channels into a perceptive color model that will separate lightness, hue and saturation channels, so that a higher weight for error diffusion will be given to the lightness channel, than to the hue channel. The motivation for this conversion is that human vision better perceives small differences of lightness in small local areas, than similar differences of hue in the same area, and even more than similar differences of saturation on the same area.

For example, if there is a small error in the green channel that cannot be represented, and another small error in the red channel in the same case, the properly weighted sum of these two errors may be used to adjust a perceptible lightness error, that can be represented in a balanced way between all three color channels (according to their respective statistical contribution to the lightness), even if this produces a larger error for the hue when converting the green channel. This error will be diffused in the neighboring pixels.

In addition, gamma correction may be needed on each of these perceptive channels, if they don't scale linearly with the human vision, so that error diffusion can be accumulated linearly to these gamma-corrected linear channels, before computing the final color channels of the rounded pixel colors, using a reverse conversion to the native non gamma-corrected image format and from which the new residual error will be computed and converted again to be distributed to the next pixels.

It should also be noted that, due to limitations of precision during the numeric conversion between color models (notably if this conversion is not linear or uses non integer weights), additional round off errors may occur that should be taken into account into the residual error.

Error diffusion with several gray levels

Error Diffusion may also be used to produce output images with more than two levels (per channel, in the case of color images). This has application in displays and printers which can produce 4, 8, or 16 levels in each image plane, such as electrostatic printers and displays in compact mobile telephones. Rather than use a single threshold to produce binary output, the closest permitted level is determined, and the error, if any, is diffused as described above.

Printer considerations

Most printers overlap the black dots slightly so there is not an exact one-to-one relationship to dot frequency (in dots per unit area) and lightness. Tone scale linearization may be applied to the source image to get the printed image to look correct.

Edge enhancement versus lightness preservation

When an image has a transition from light to dark the error diffusion algorithm tends to make the next generated pixel be black. Dark to light transitions tend to result in the next generated pixel being white. This causes an edge enhancement effect at the expense of gray level reproduction accuracy. This results in error diffusion having a higher apparent resolution than halftone methods. This is especially beneficial with images with text in them such as the typical facsimile.

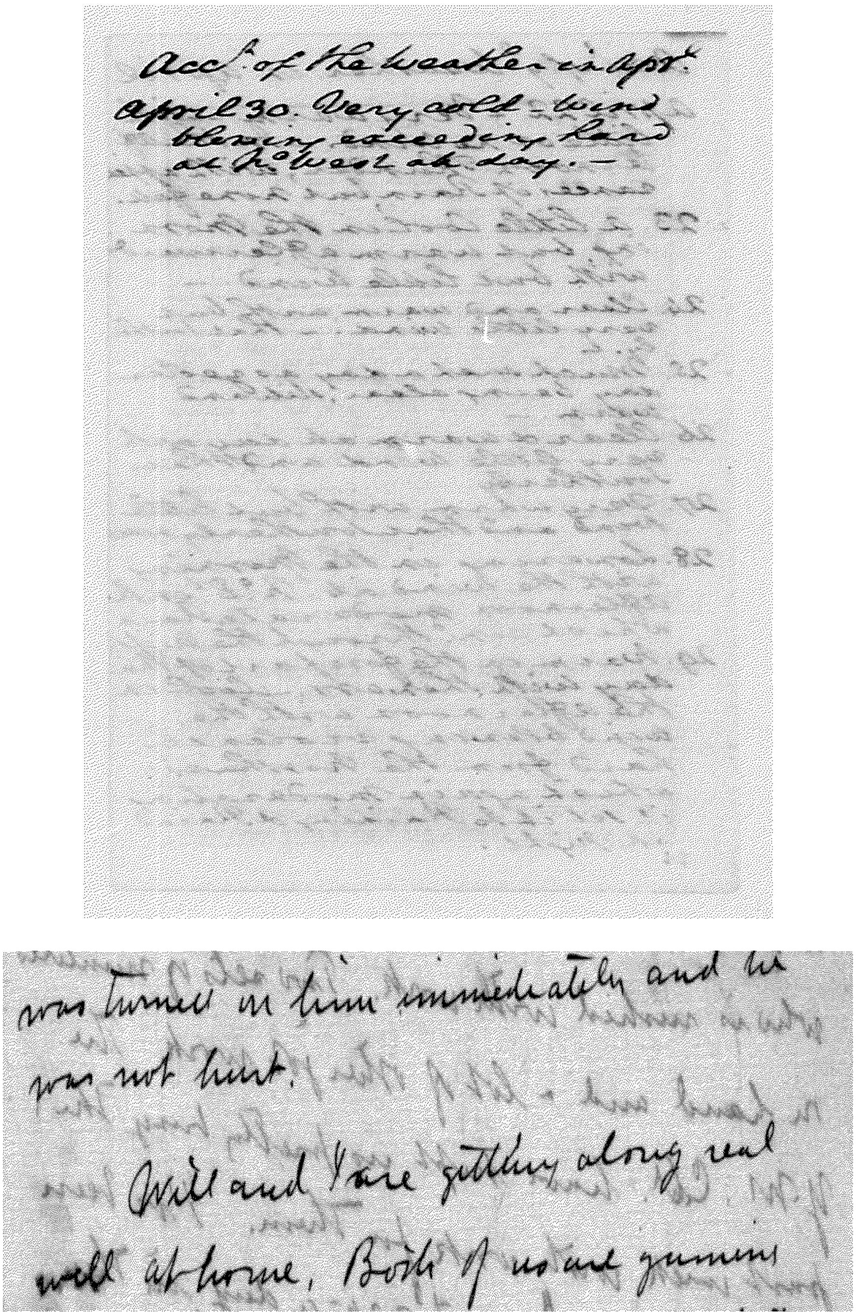
This effect shows fairly well in the picture at the top of this article. The grass detail and the text on the sign is well preserved, and the lightness in the sky, containing little detail. A cluster-dot halftone image of the same resolution would be much less sharp.

Some popularly used weight kernels are discussed here with corresponding results.

Floyed Steinberg kernel:

The first and most famous 2D error diffusion formula was published by Robert Floyd and Louis Steinberg in 1976[15].It diffuses errors in the following pattern. Error accumulated for individual pixels (denoted with 'X') were diffused to 4-neighboring pixels with the following weight kernels.

	X	**7/16**
3/16	**5/16**	**1/16**


Acct. of the weather in Apr.
April 30. Very cold - wind
blowing exceeding hard
at No West all day. -

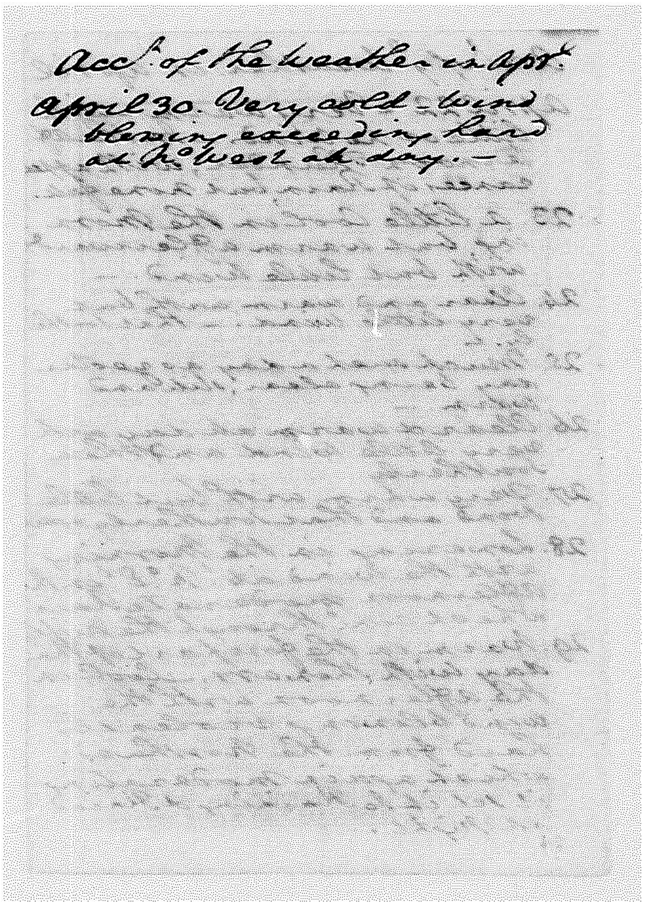
was turned on him immediately and he
was not hurt.
Will and I are getting along real
well at home, Both of us are gunning

Fig.3.6. Examples of Floyed Steinberg halftoning.

Jarvis kernel:

In the same year that Floyd and Steinberg published their famous dithering algorithm, a lesser-known – but much more powerful – algorithm was also published. The Jarvis, Judice, and Ninke filter is significantly more complex than Floyd-Steinberg [15] and a 12 elements error filter as shown below was used. With this algorithm, the error is distributed to three times as many pixels as in Floyd-Steinberg, leading to much smoother – and more subtle – output. Unfortunately, the divisor of 48 is not a power of two, so bit-shifting can no longer be used – but only values of 1/48, 3/48, 5/48, and 7/48 are used, so these values can each be calculated but once, then propagated multiple times for a small speed gain.

		X	**7/48**	**5/48**
3/48	**5/48**	**7/48**	**5/48**	**3/48**
1/48	**3/48**	**5/48**	**3/48**	**1/48**



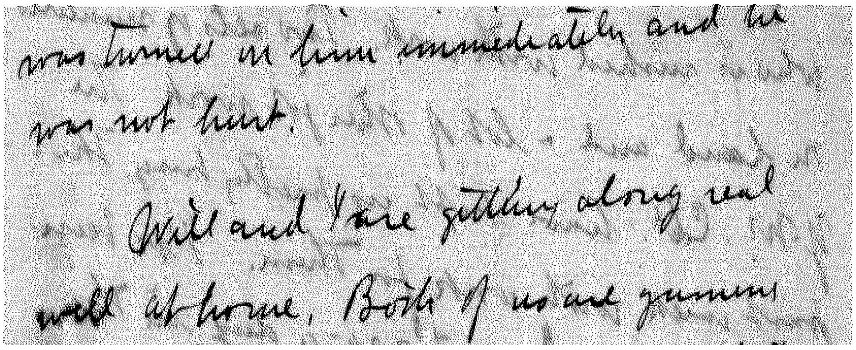


Fig.3.7. Examples of Jarvis halftoning

Stucki kernel:

Five years after Jarvis, Judice, and Ninke published their dithering formula, Peter Stucki published an adjusted version of it, with slight changes made to improve processing time. Stucki [17] have some different weight filter as shown below.

		X	**8/42**	**4/42**
2/42	**4/42**	**8/42**	**4/42**	**2/42**
1/42	**2/42**	**4/42**	**2/42**	**1/42**

The divisor of 42 is still not a power of two, but all the error propagation values are – so once the error is divided by 42, bit-shifting can be used to derive the specific values to propagate. For most images, there will be minimal difference between the output of Stucki and JJN algorithms, so Stucki is often used because of its slight speed increase.

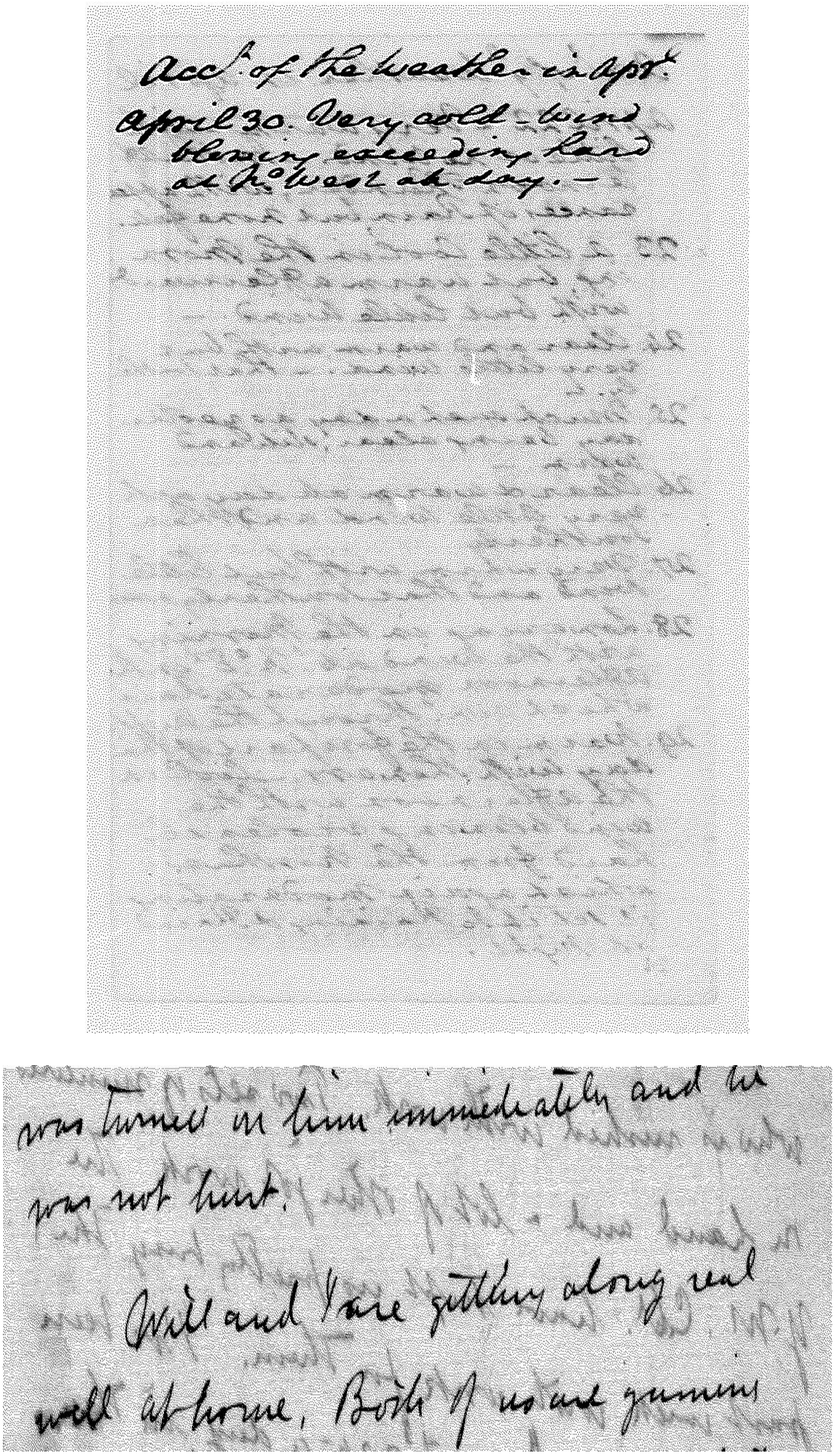


Fig.3.8. Examples of Stucki halftoning

The halftone results clearly shows that the error diffusion algorithm provides smoother transitions between the different tonal values. Hence, this technique can be considered for further analysis as provide in the following section.

3.3. Analysis of error diffusion halftone results

The enlarged views of the three important regions that are pure background, background with show through texts/patterns and texts show that the binary patterns appearing in them are considerably different. It can be easily seen that the distribution of the black and white pixels are rendering different patterns in the three regions as shown in following images.

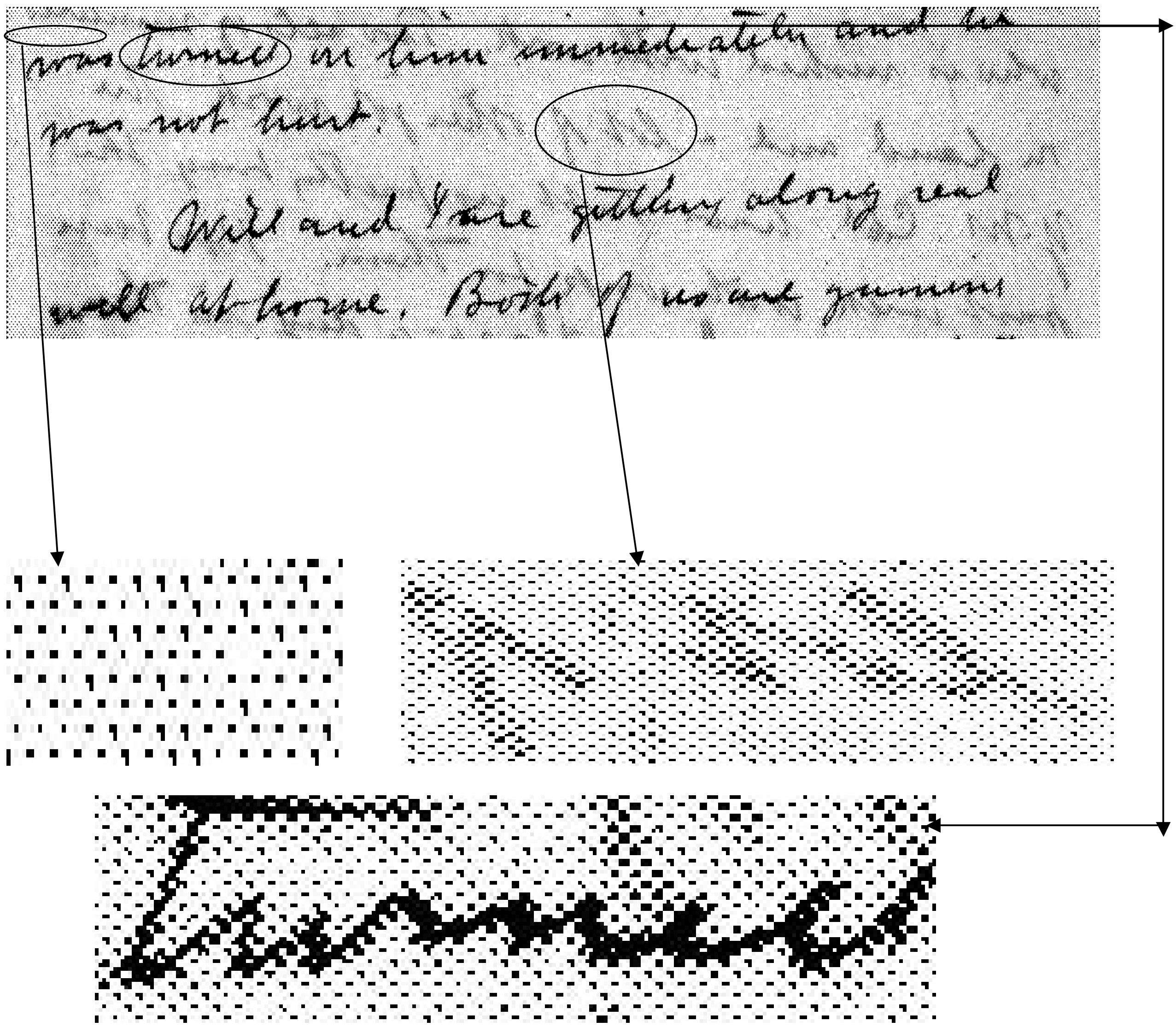


Fig.3.9. Images of three distinct binary regions using CDOD halftoning

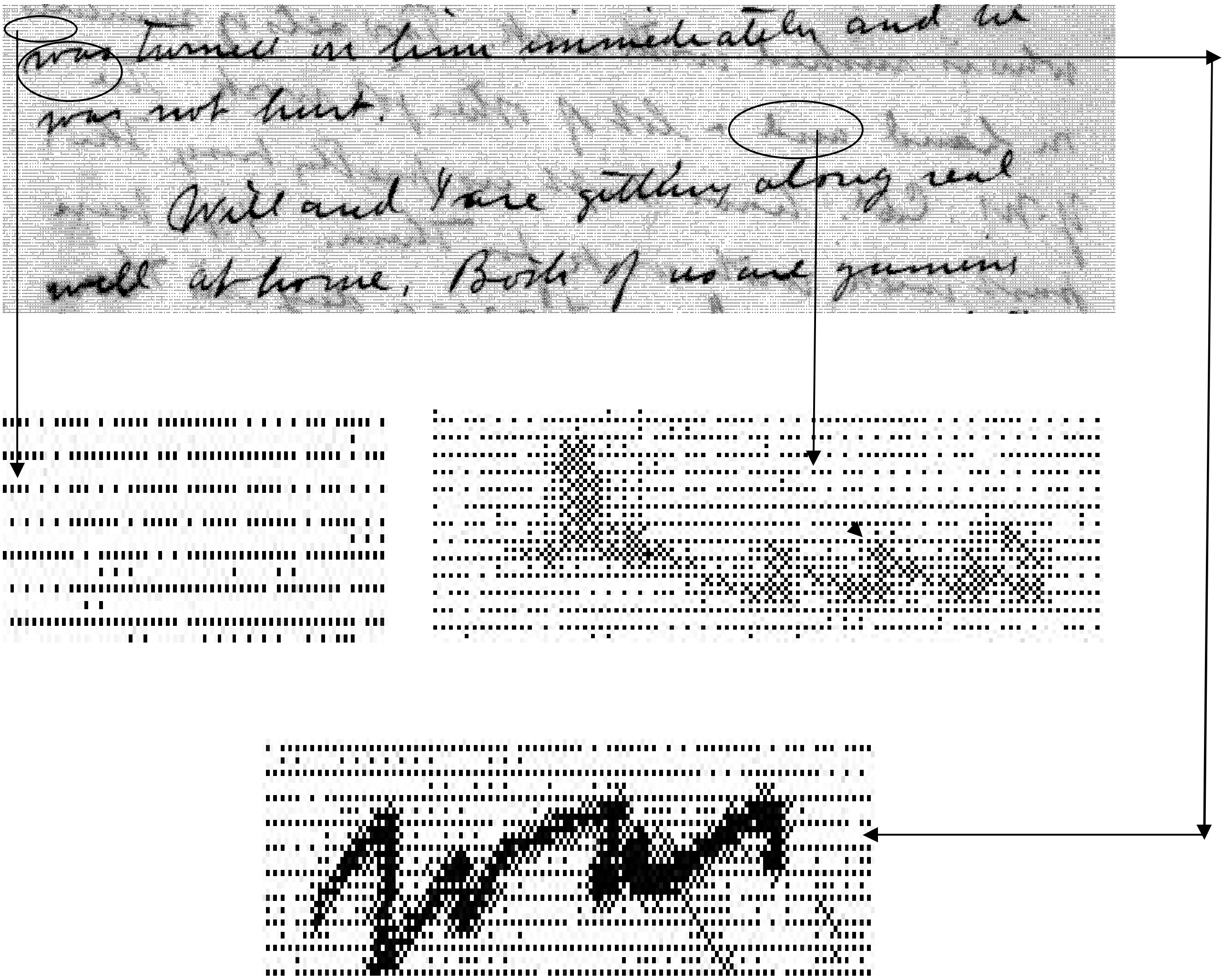


Fig.3.10. Images of three distinct binary regions using DDOD halftoning

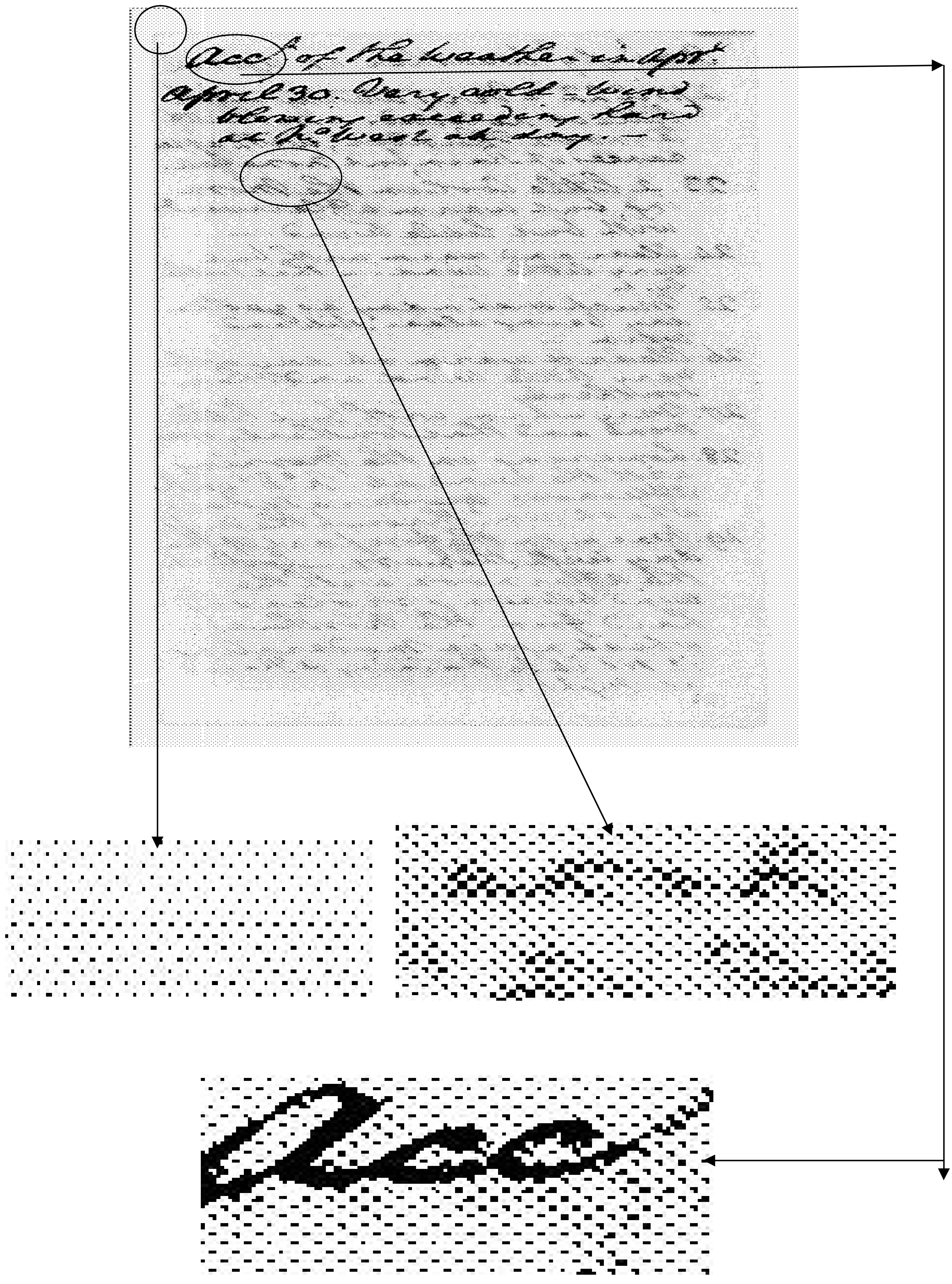


Fig.3.11.Images of three distinct binary regions using CDOD halftoning

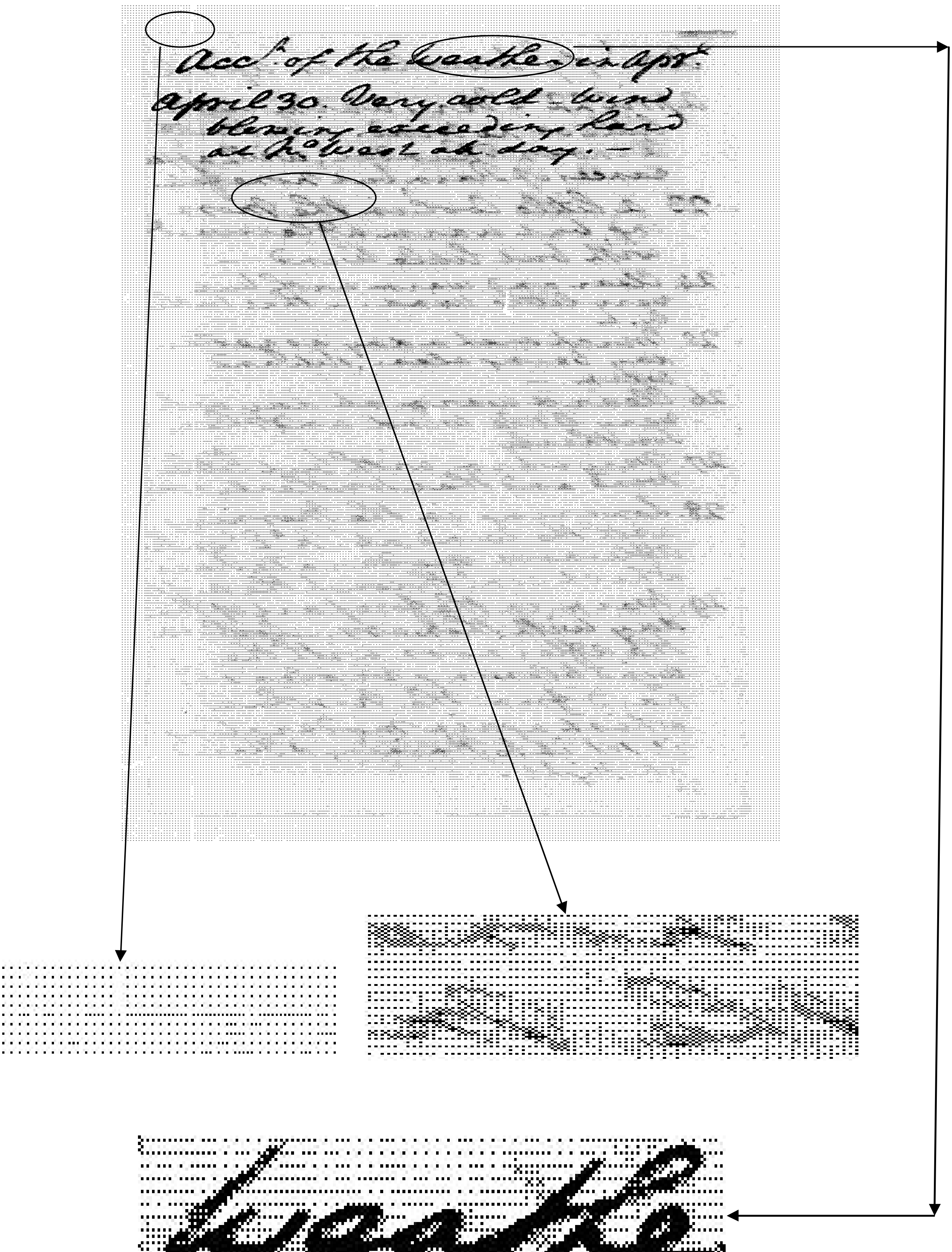


Fig. 3.12**.** Images of three distinct binary regions using DDOD halftoning

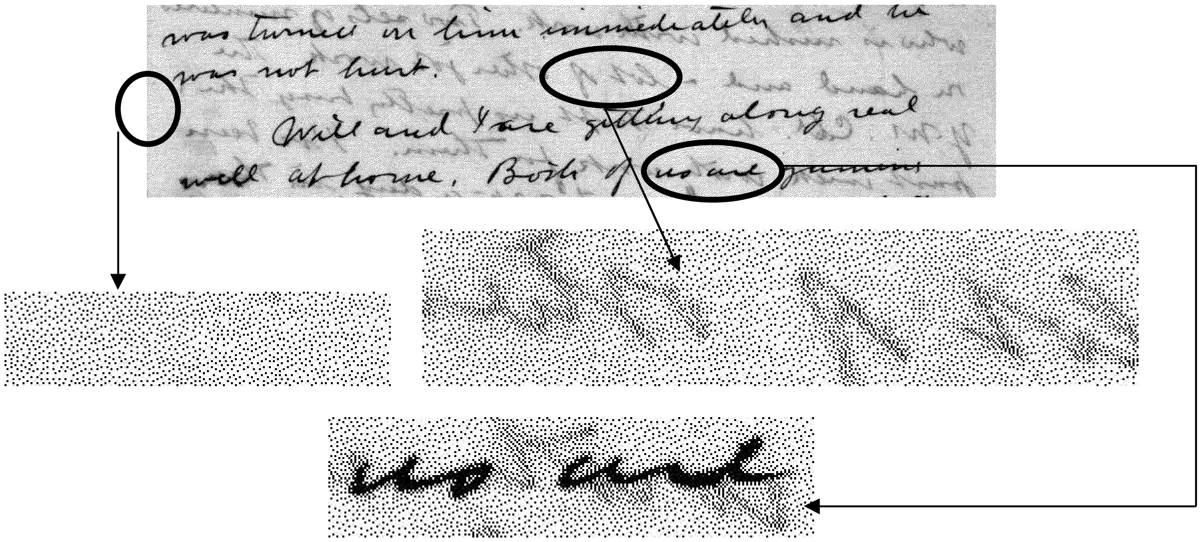


Fig. 3.13. Images of three distinct binary regions using Floyed-Steinberg kernel

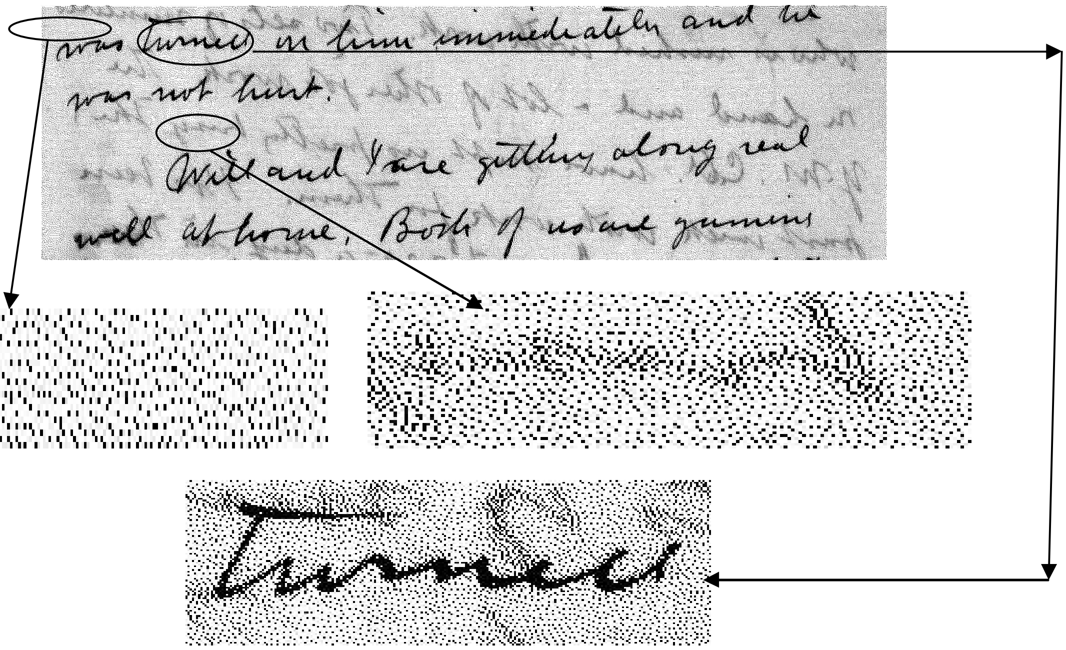


Fig. 3.14**.** Images of three distinct binary regions using Jarvis kernel

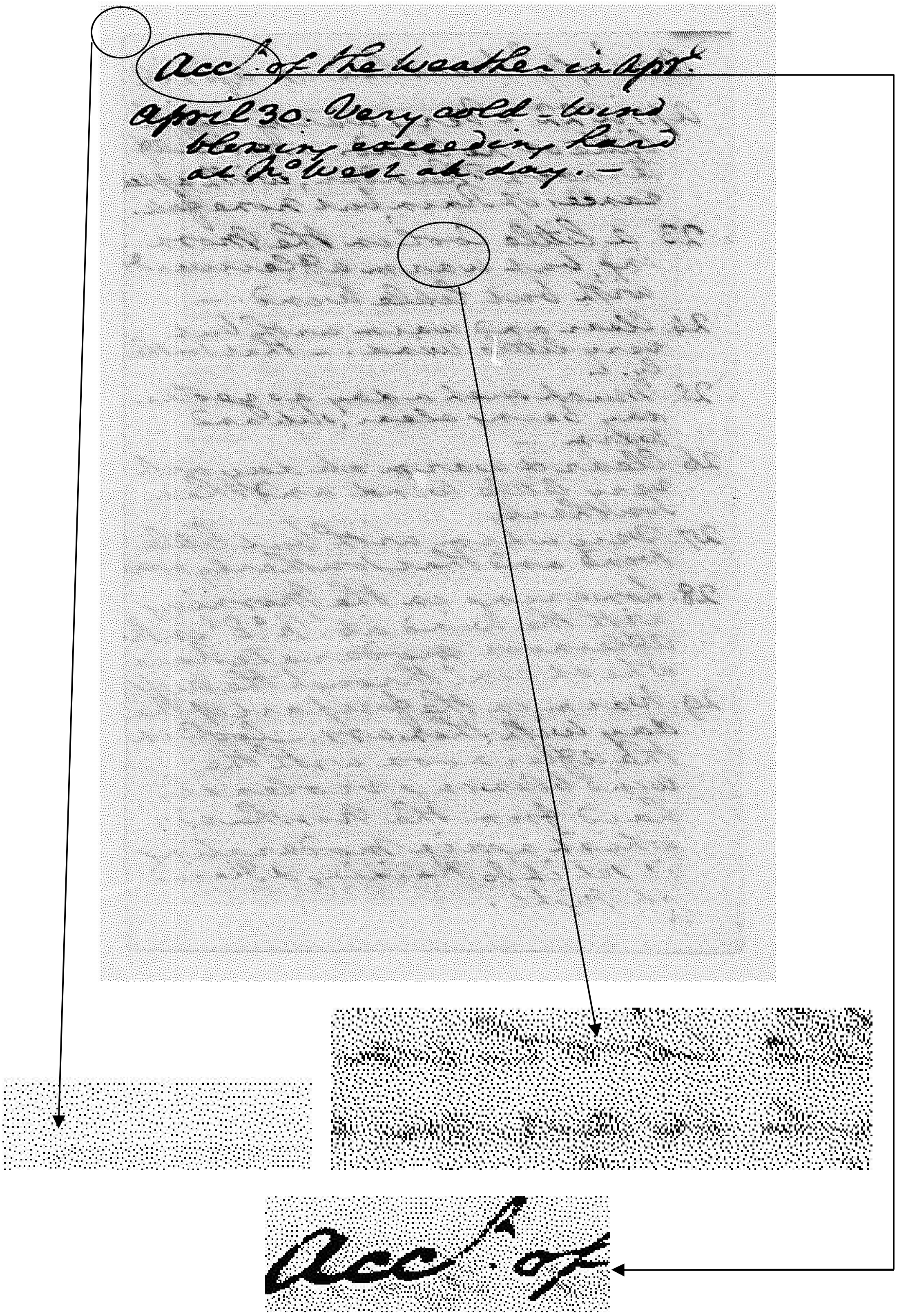


Fig. 3.15. Images of three distinct binary regions using Floyed-Steinberg kernel

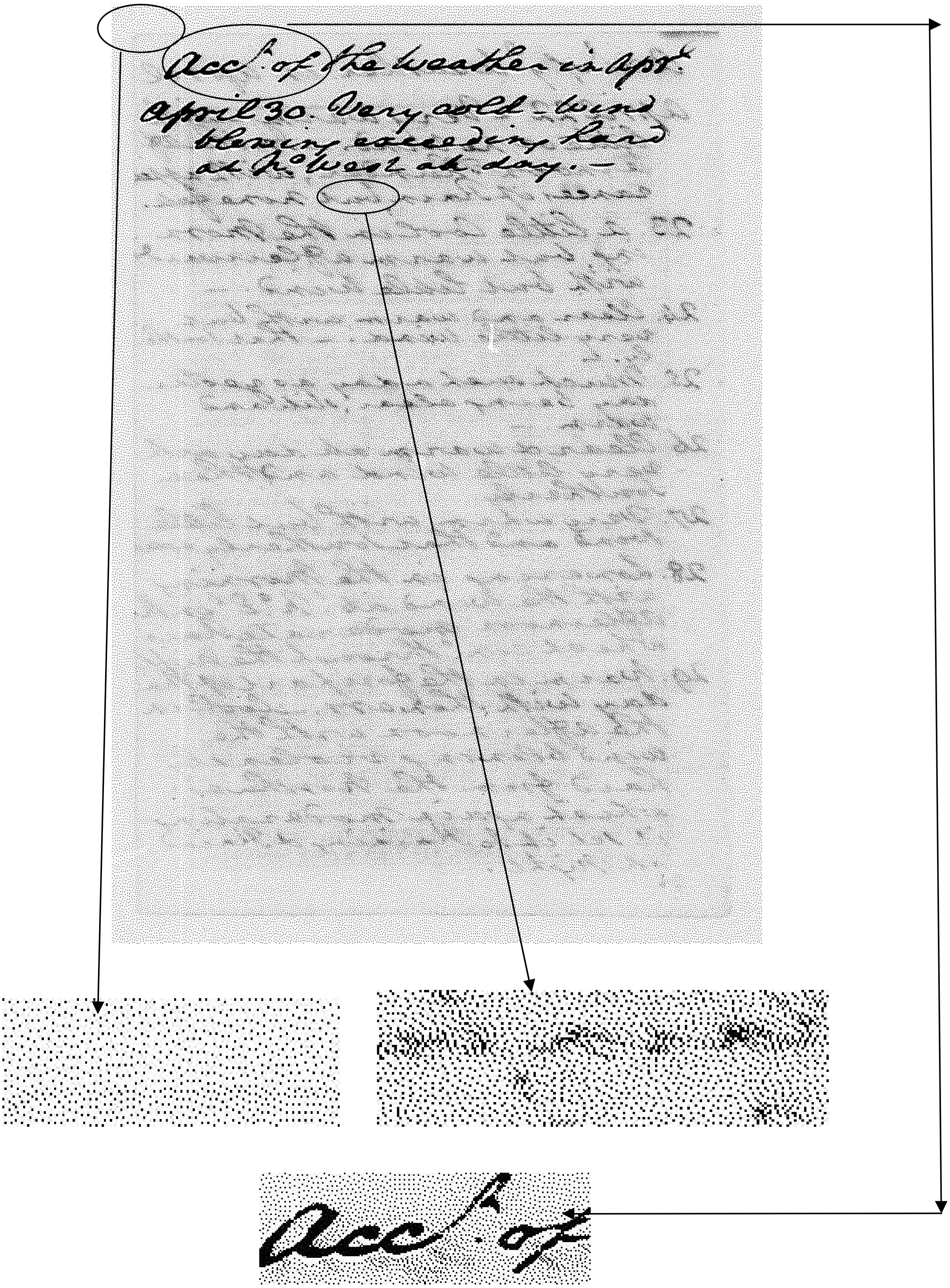


Fig. 3.16. Images of three distinct binary regions using Jarvis kernel

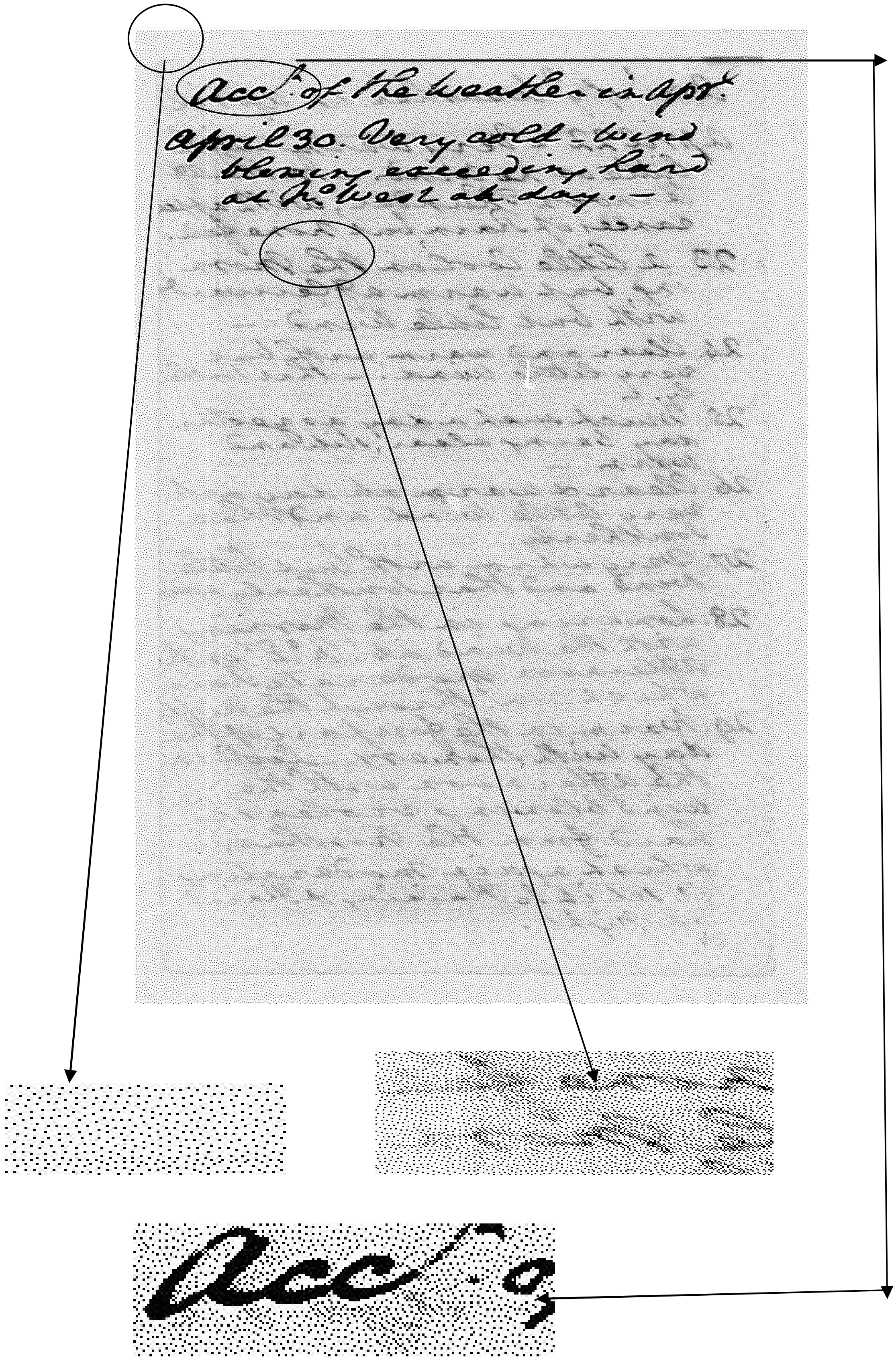


Fig.3.17. Images of three distinct binary regions using Stucki kernel

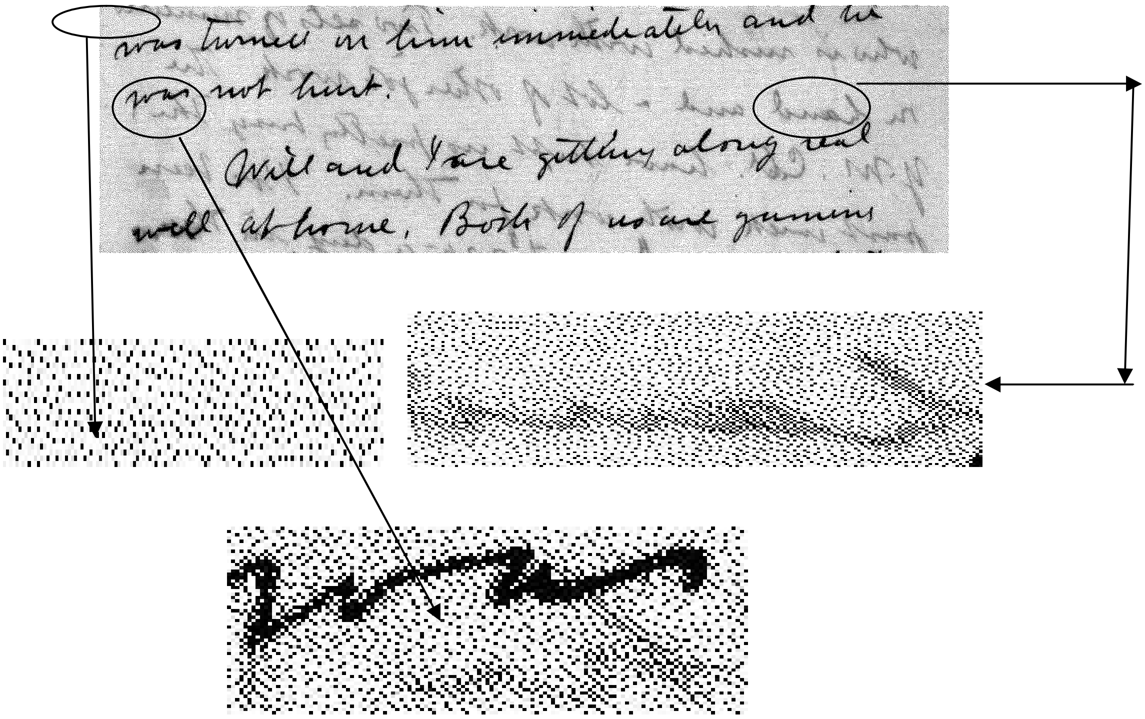


Fig. 3.18. Images of three distinct binary regions using Stucki kernel

The above figures clearly show that the background, show-through regions are having different distribution of black and white dots. They are also having different clustering patterns. Such pattern-wise difference may be helpful in order to segregate between them towards document image restoration. The following chapter shows the possible segmentation and restoration performed in the halftone images.

3.4. Conclusions

This chapter introduces the possibility of halftoning techniques towards segregating the different regions in show-through affected documents. Unlike standard techniques this technique does not perform a thresholding rather it renders the different regions with the corresponding tonal variations. The results with different halftoning techniques been analysed here and found that the error diffusion technique is providing a better and clearer distribution of black and white dots. Three popular error kernels were studied and found all of them are showing significant difference in terms of distribution pattern in the different regions. This motivates towards using such distribution characteristics in order to segregate between different regions which in-turn will be used for image restoration cancelling the show-through effects.

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CHAPTER- 4

Neighborhood Based Post processing

4.1. Introduction

From previous chapter it has been seen among halftoning techniques error diffusion acts better. So here error diffusion is used for further neighbourhood based post processing. Three popular kernel of error diffusion is used. Order statistics filtering based approach are studied based on statistics characteristics. Here each pixel of the halftone image is taken and the order statistics filters are applied on a k x k window centred at pixel under processing.

Order statistics filters deal with the different statistical moments such as mean, median, mode, max, minimum, etc. within a set window centred at the pixel under processing. These filters are popularly used for different image processing applications including denoising of the images [12]. In this chapter each of such filters been tested for the post processing purpose. The filtered image again been subjected to a thresholding operation for final decision about whether a pixel is a part of background or text. However median filtering need not any such thresholding since the filtered value is in binary mode.

The window size also may play important role on the final output. Hence, tests have been performed on three window sizes i.e. 3x3 5x5 and 7x7. A bigger window than these may cause loss of information as in general the order statistics filters provide smoothing. The results with each of filters with different window size as well as threshold values are presented in this chapter. Based on the results the selection of statistical filter was made and the decision goes in favour of mean and median filters. The tests were also extended to rank order filters and found that such filters can provide output that are equivalent to mean and median filters output.

4.2. Order statistics filters

4.2.1. Mean Filter: Mean filter is a simple sliding–window spatial filter that replaces the centre pixel in the window with the average or mean of all the pixel values in the window.

Advantage: It smoothes an image and also reduces the noise.

Disadvantage: Some sharp details are lost.

Remedy: Linear spatially variant filter can be used .Here more smoothing takes place where there are no sharp details.

	1	**1**	**1**
1/9	**1**	**1**	**1**
	1	**1**	**1**

Linear Spatially Invariant filter

4.2.2. Median Filter: It is a non-linear filter based on order statistics. This filter is also spatially invariant. Replace each pixel with the median of the gray values in the local neighbourhood. It is very effective in removing salt and pepper noise and can retain image details to a reasonable extent. Median filter is more effective (robust to outliers) than the mean filter as it does not depend on extreme values.

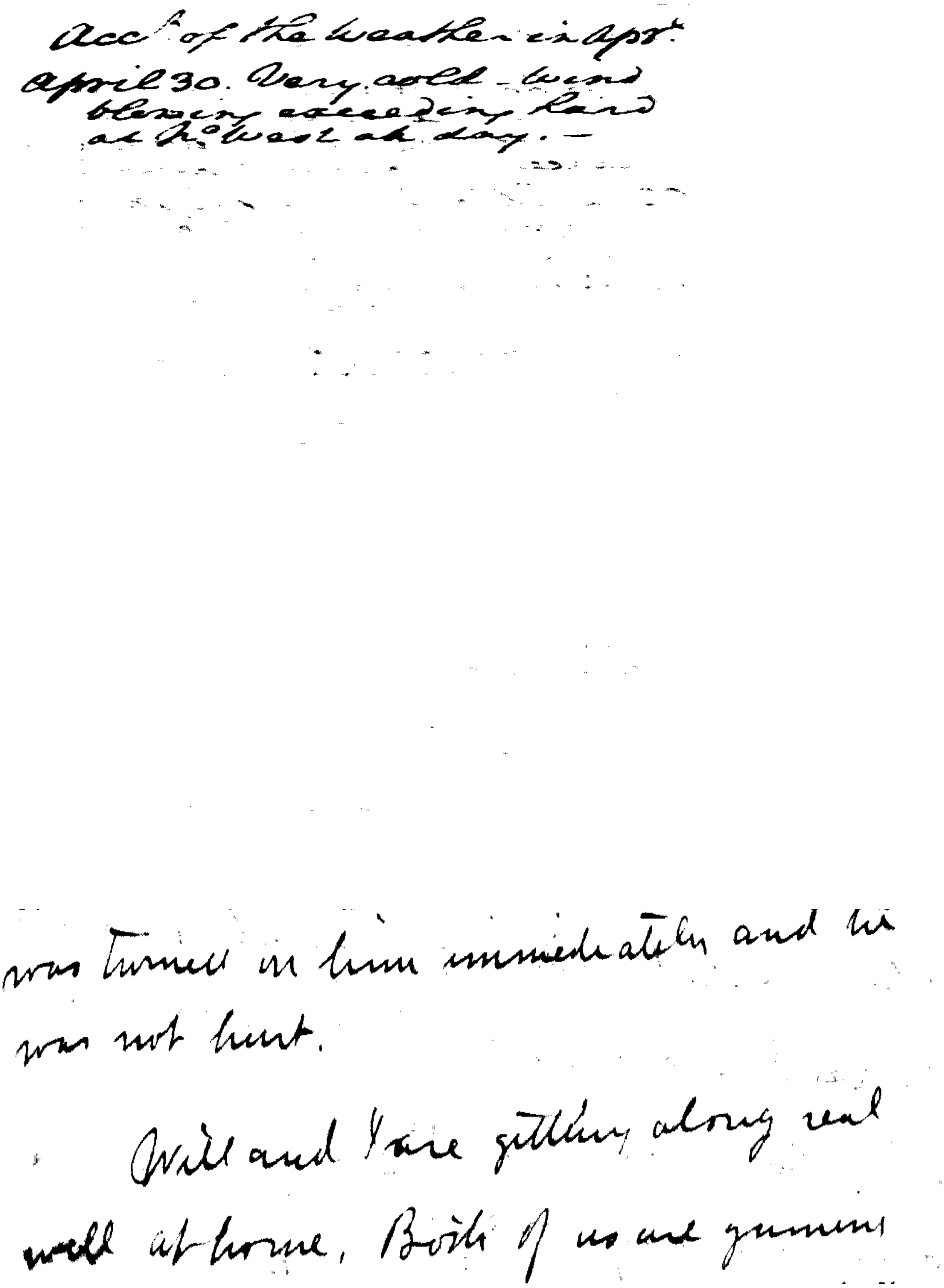
4.2.3.Maximum filter: Here in case of maximum filter current pixel replace by maximum pixel value of its neighboring pixels. It is very effective in case of pepper noise. Here 3× 3 window is taken.

4.2.4.Minimum filter: Here in case of minimum filter current pixel replace by minimum pixel value of its neighboring pixels. It is very effective in case of salt noise. Here 3× 3 window is taken.

4.2.5.New Rank-order filter: Here in this thesis a new Rank order filter is used based on median filter and the results are much better than the standard order statistics filters like, maximum and minimum filters.

4.3. Output of filtering and binarization:

In this section the experimental results obtained using different filtering on the halftone images are presented. This study was performed to select the optimum filtering for post-processing.


Acct of the weather in Apr.
April 30. Very cold - wind
blowing exceeding hard
at No West all day. —

was turned on him immediately and he
was not hurt.
Will and I are getting along real
well at home, Both of us are gaining

Fig.4.1. Mean filter applied on Floyd-Steinberg error-diffusion output (threshold value 0.4 and window size 3×3)

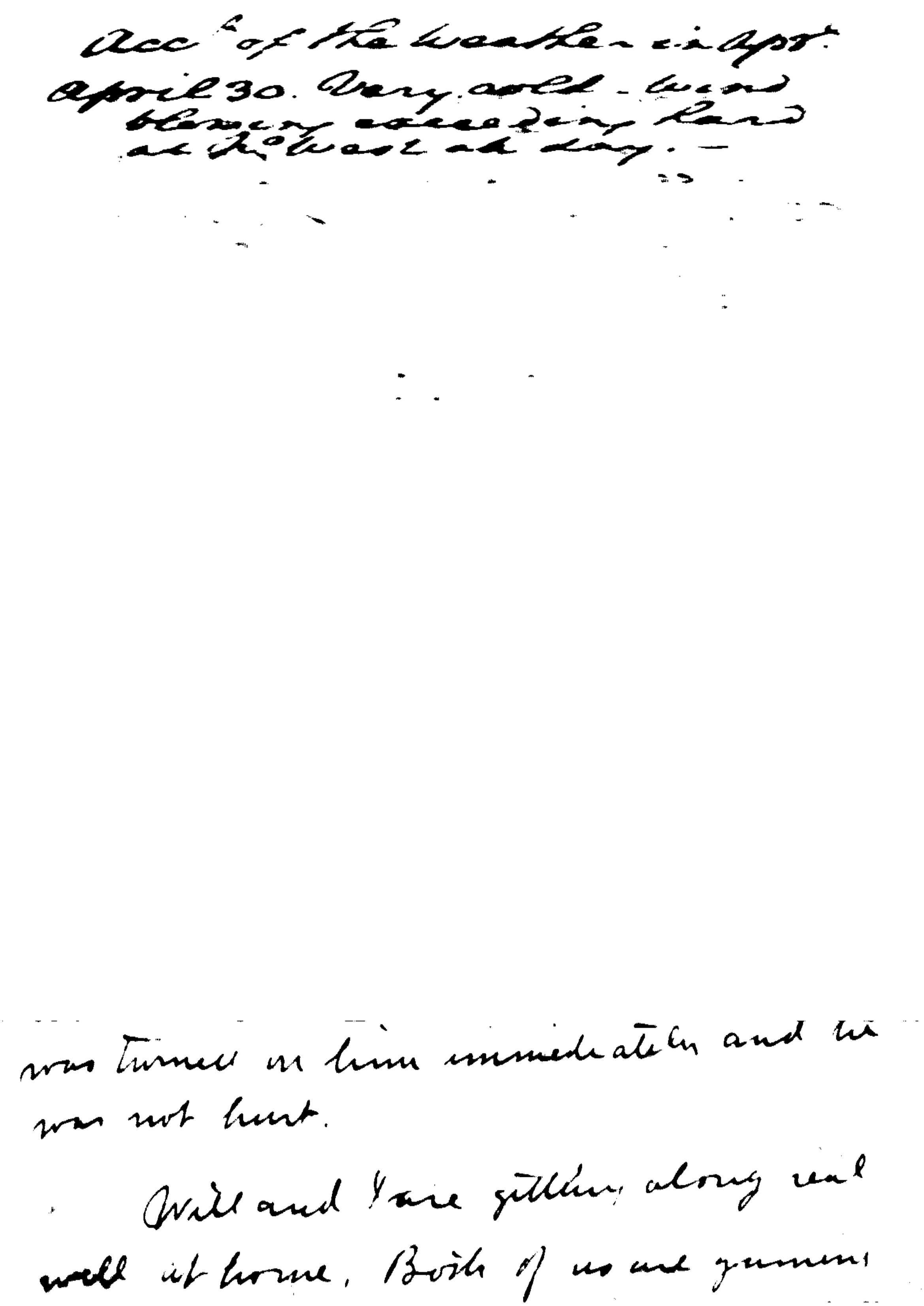


Fig.4.2. Mean filter applied on Floyd-Steinberg error-diffusion output (threshold value 0.4 and window size 5×5)

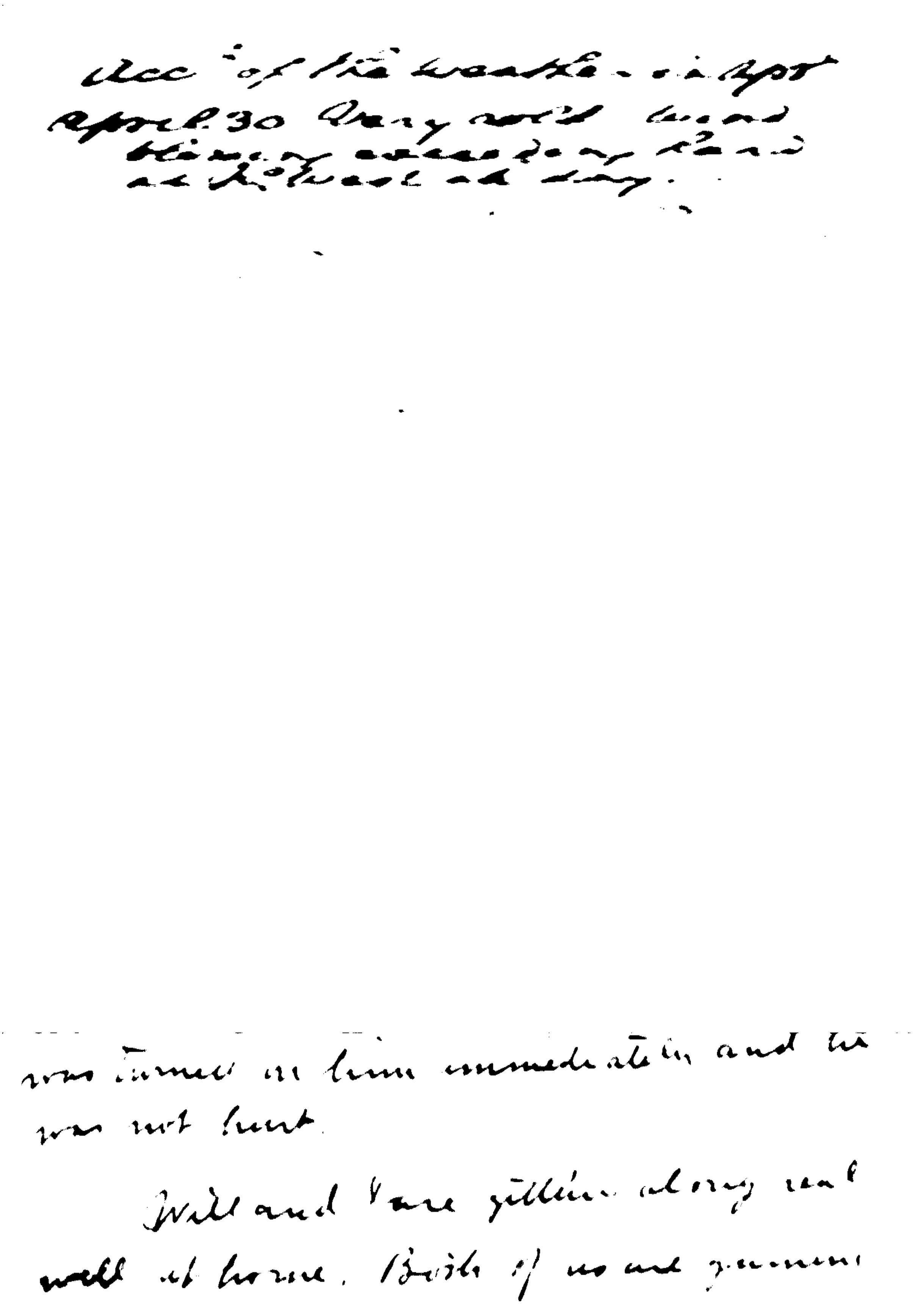


Fig.4.3. Mean filter applied on Floyd-Steinberg error-diffusion output (threshold value 0.4 and window size 7×7)

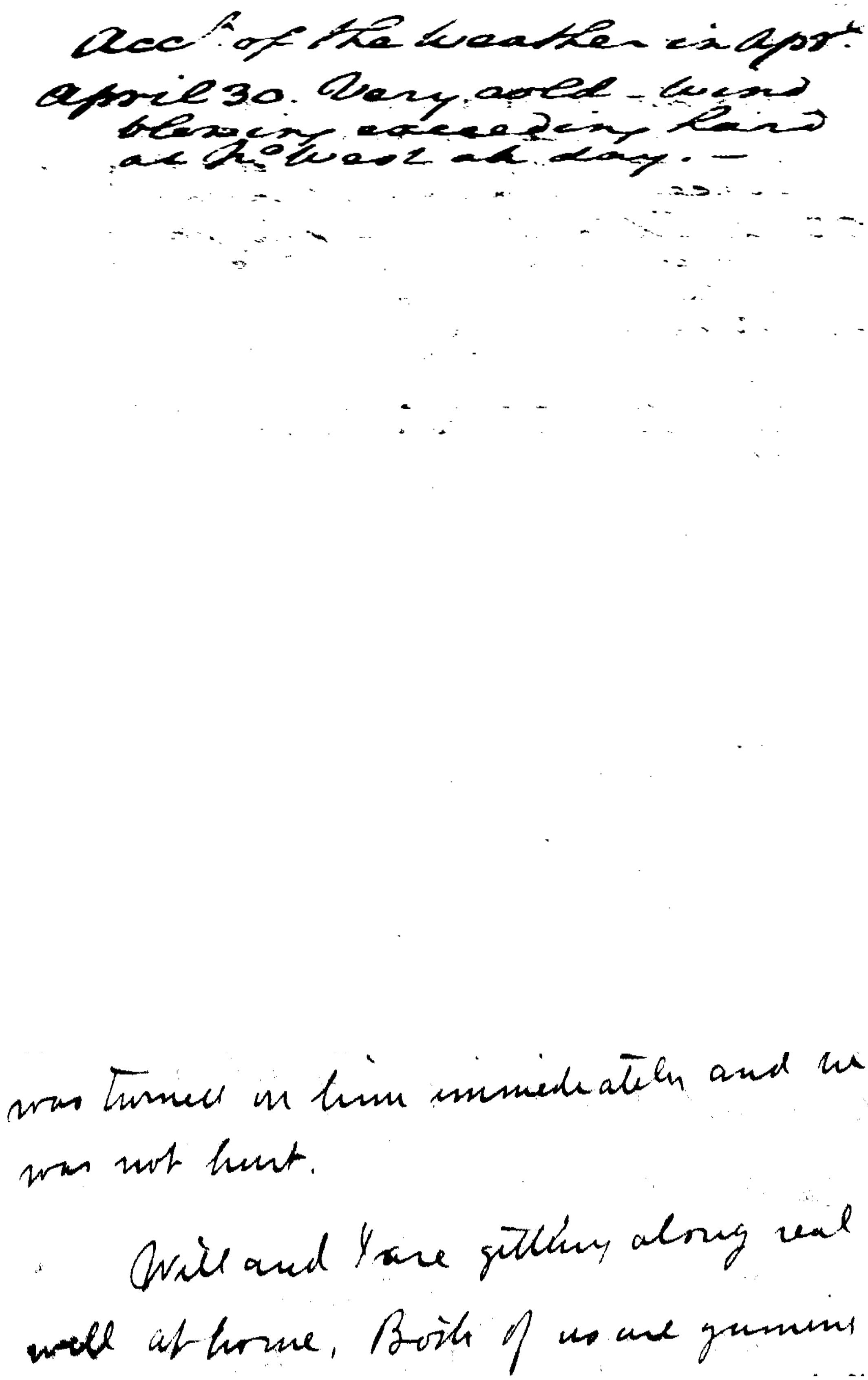


Fig.4.4. Mean filter applied on Jarvis error-diffusion output (threshold value 0.4 and window size 3×3)

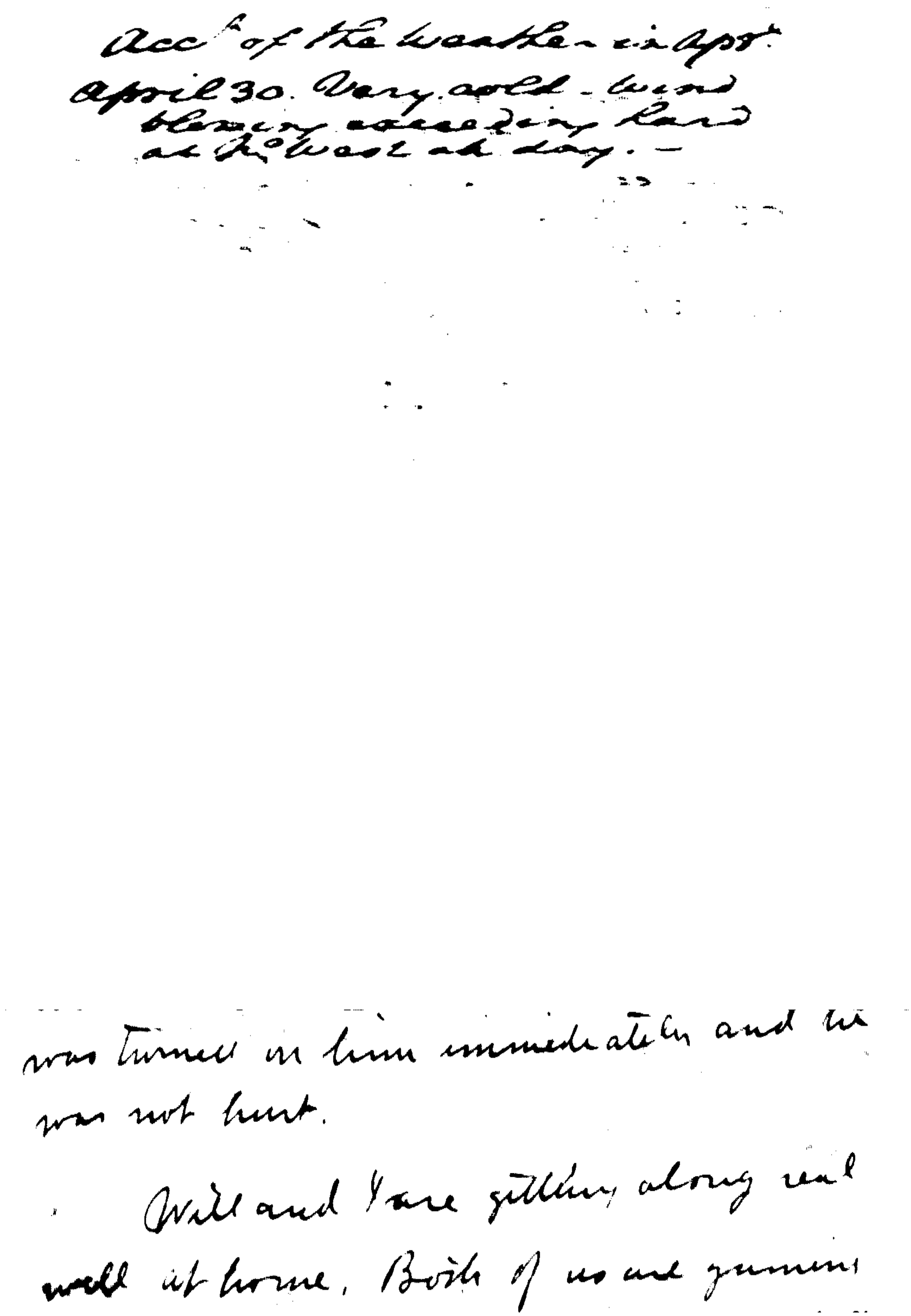


Fig.4.5. Mean filter applied on Jarvis error-diffusion output (threshold value 0.4 and window size 5×5)

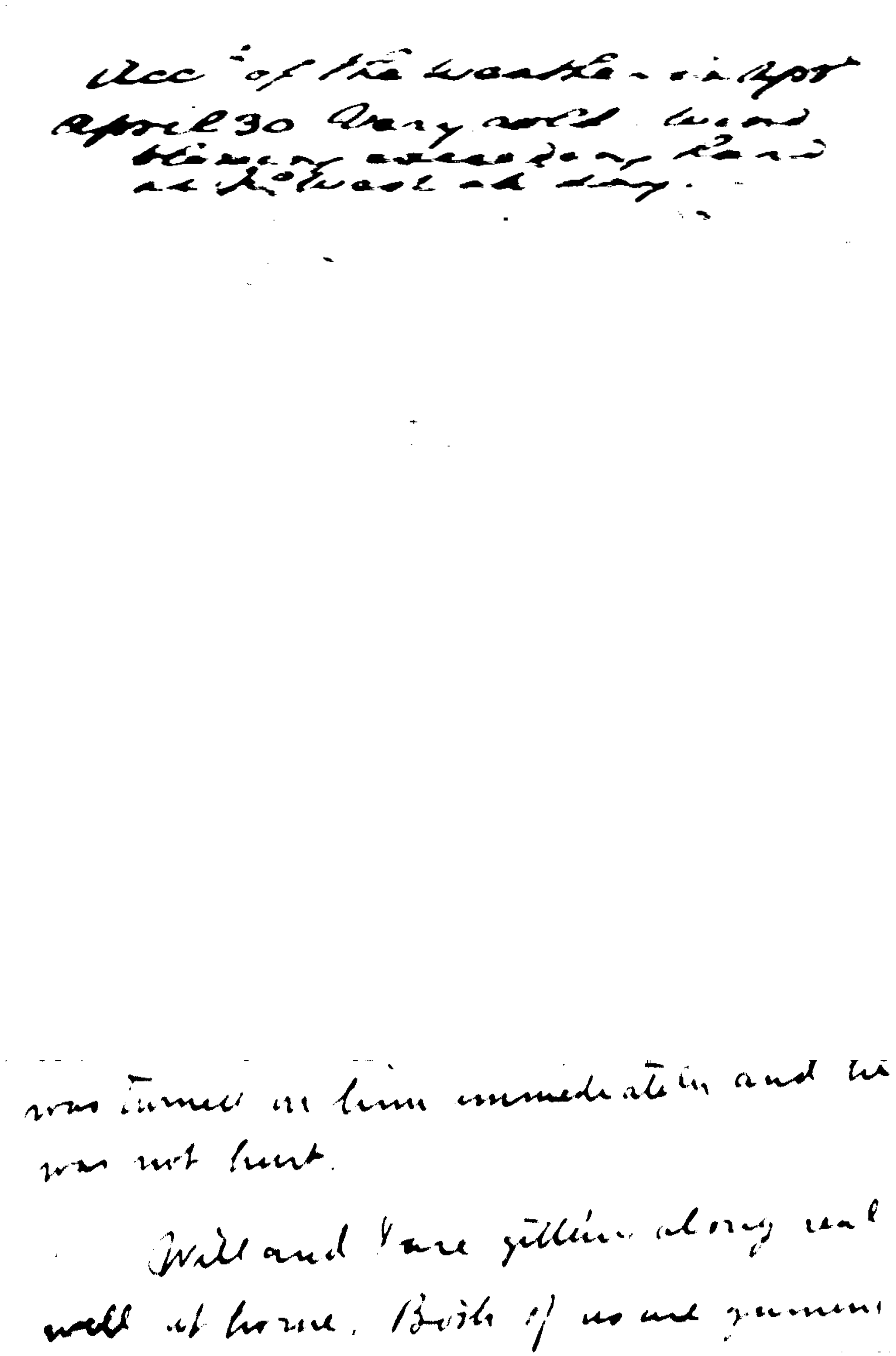


Fig.4.6. Mean filter applied on Jarvis error-diffusion output (threshold value 0.4 and window size 7×7).

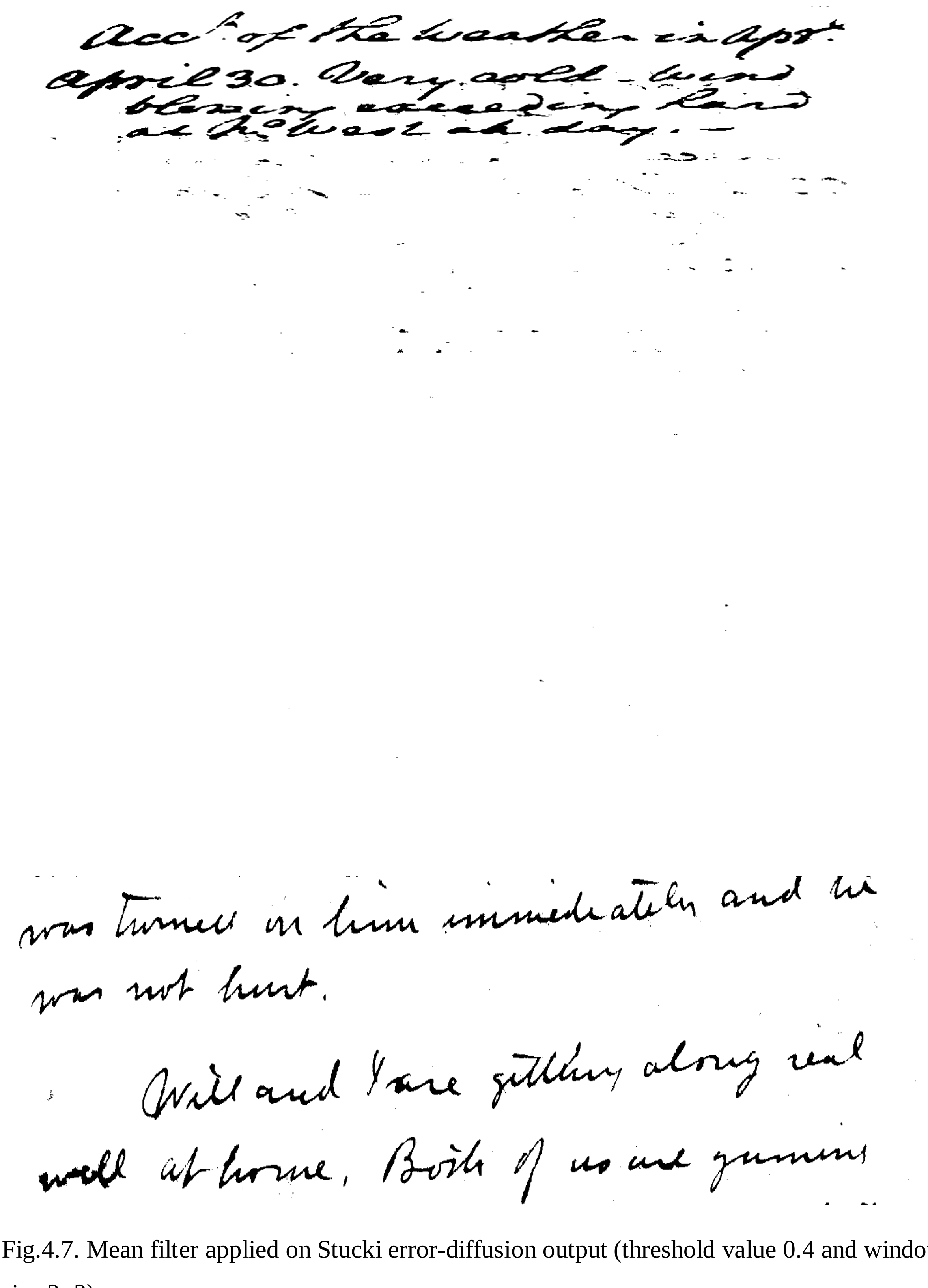


Fig.4.7. Mean filter applied on Stucki error-diffusion output (threshold value 0.4 and window size 3×3)

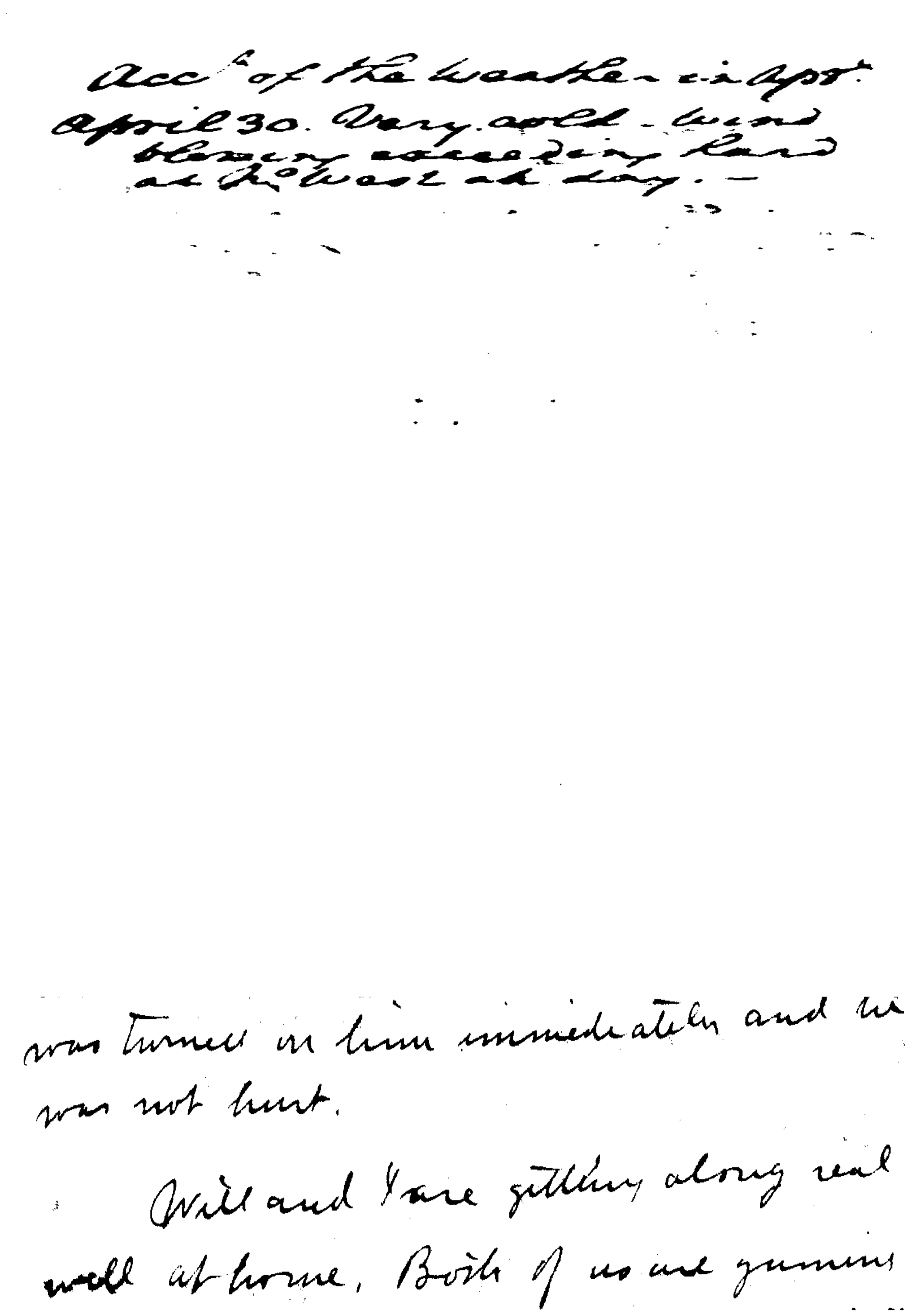


Fig.4.8. Mean filter applied on Stucki error-diffusion output (threshold value 0.4 and window size 5×5)

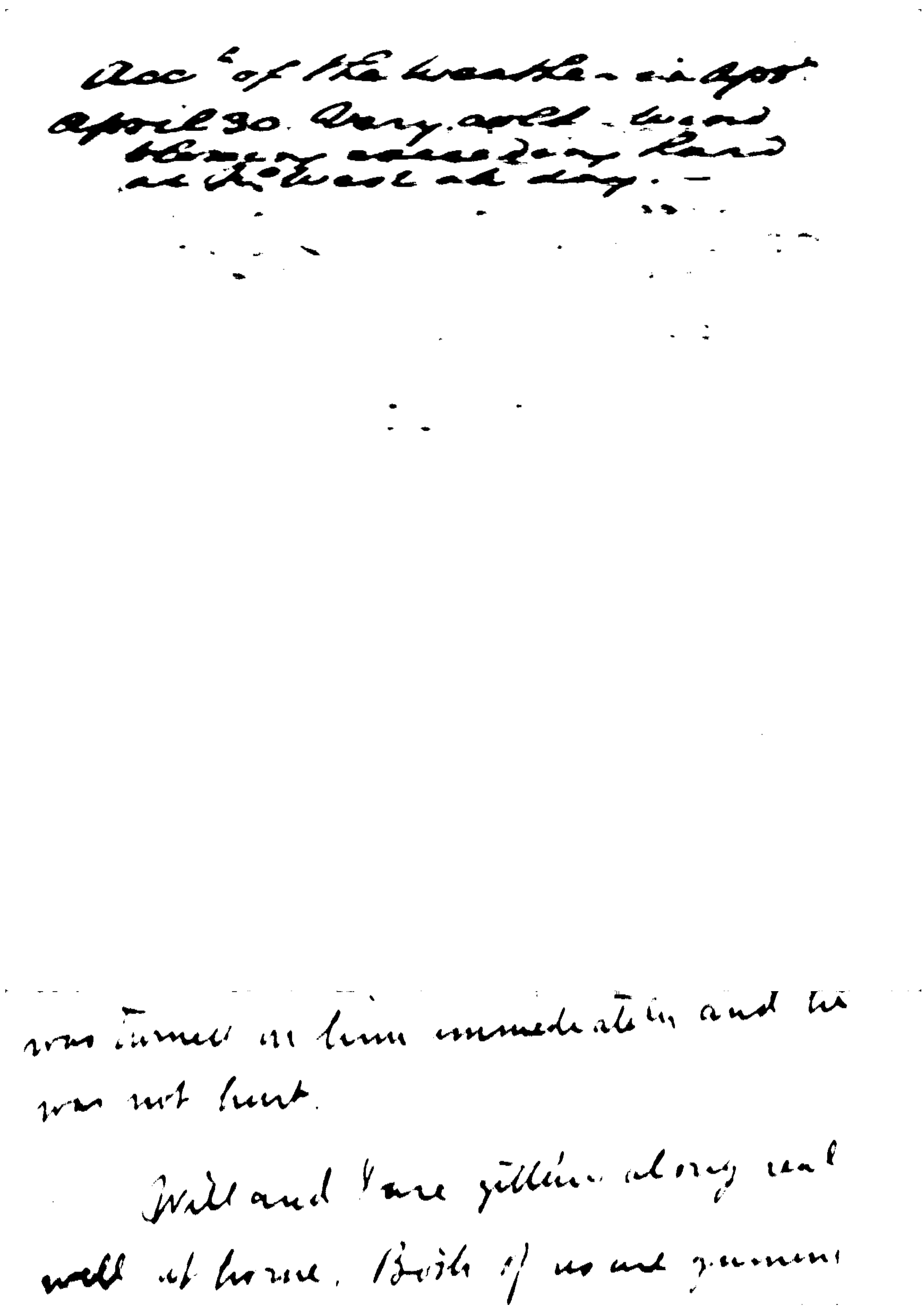


Fig.4.9. Mean filter applied on Stucki error-diffusion output (threshold value 0.4 and window size 7×7)

As the window size is increased the background noise is getting reduced but the foreground is also not very clear and some portion of the text are broken in case of 5×5,7×7 window size whereas in case of 3×3 window the text portion is clear.

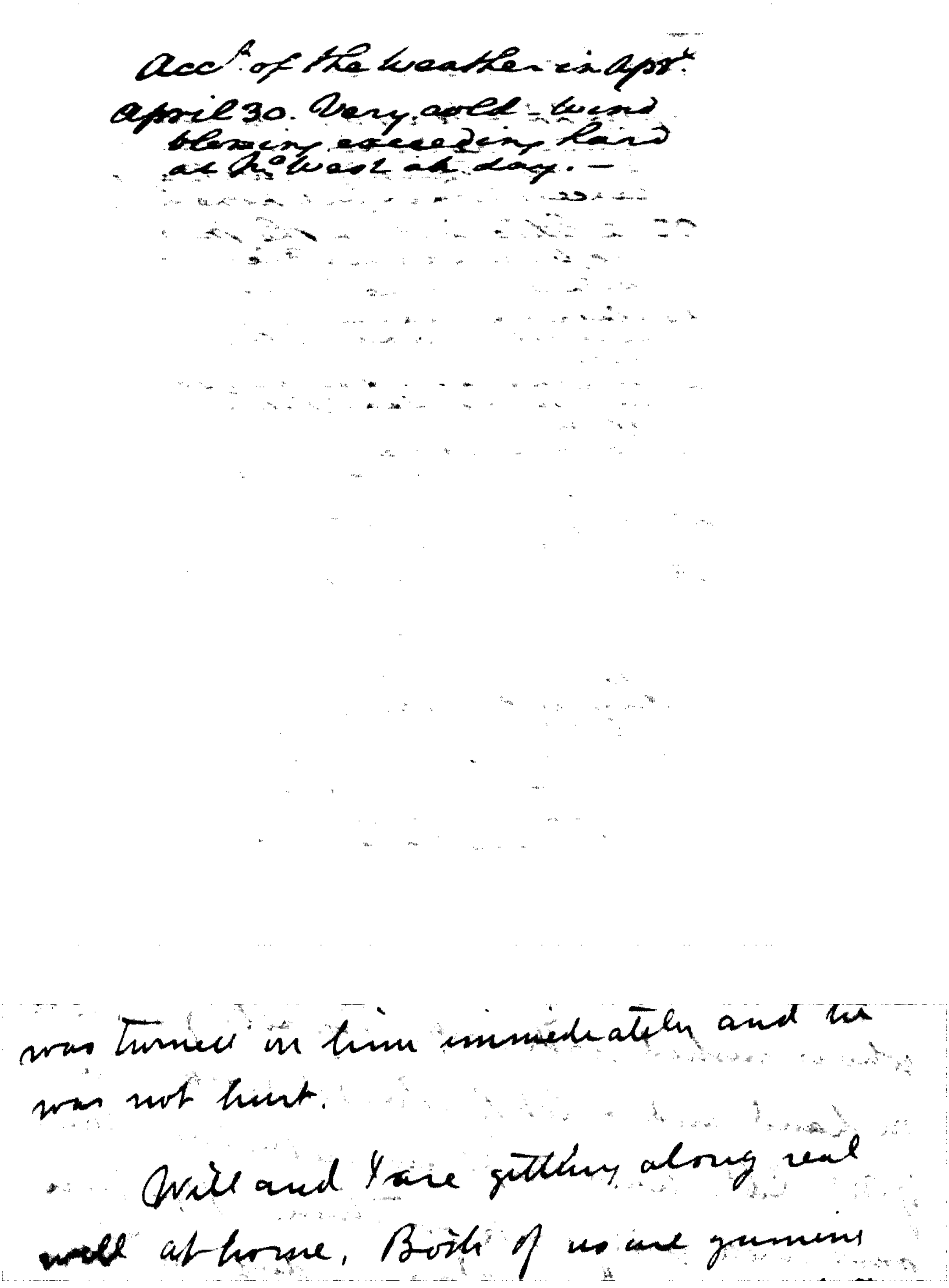


Fig.4.10. Median filter applied on Floyd-Steinberg error-diffusion output (window size 3×3)

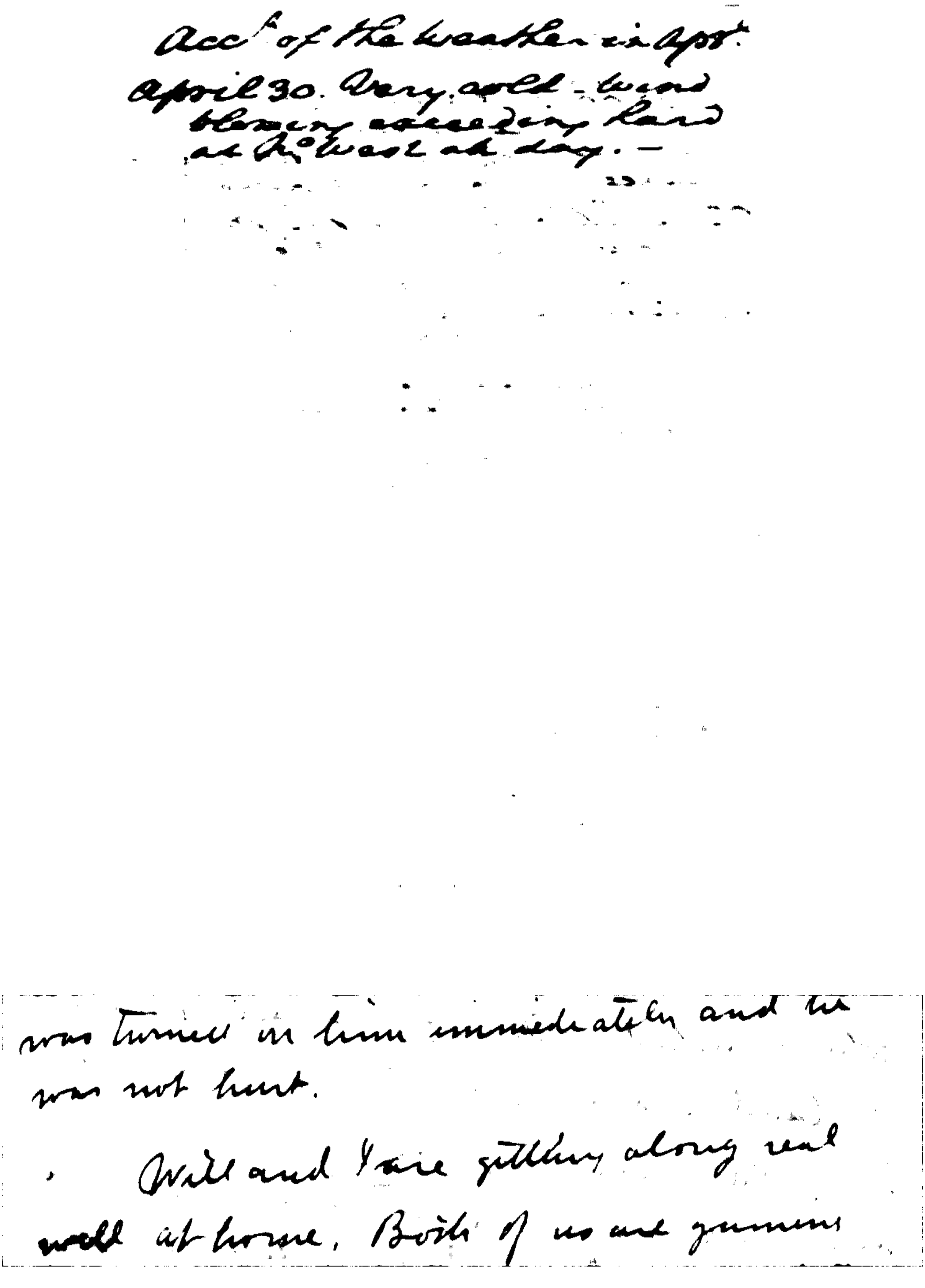
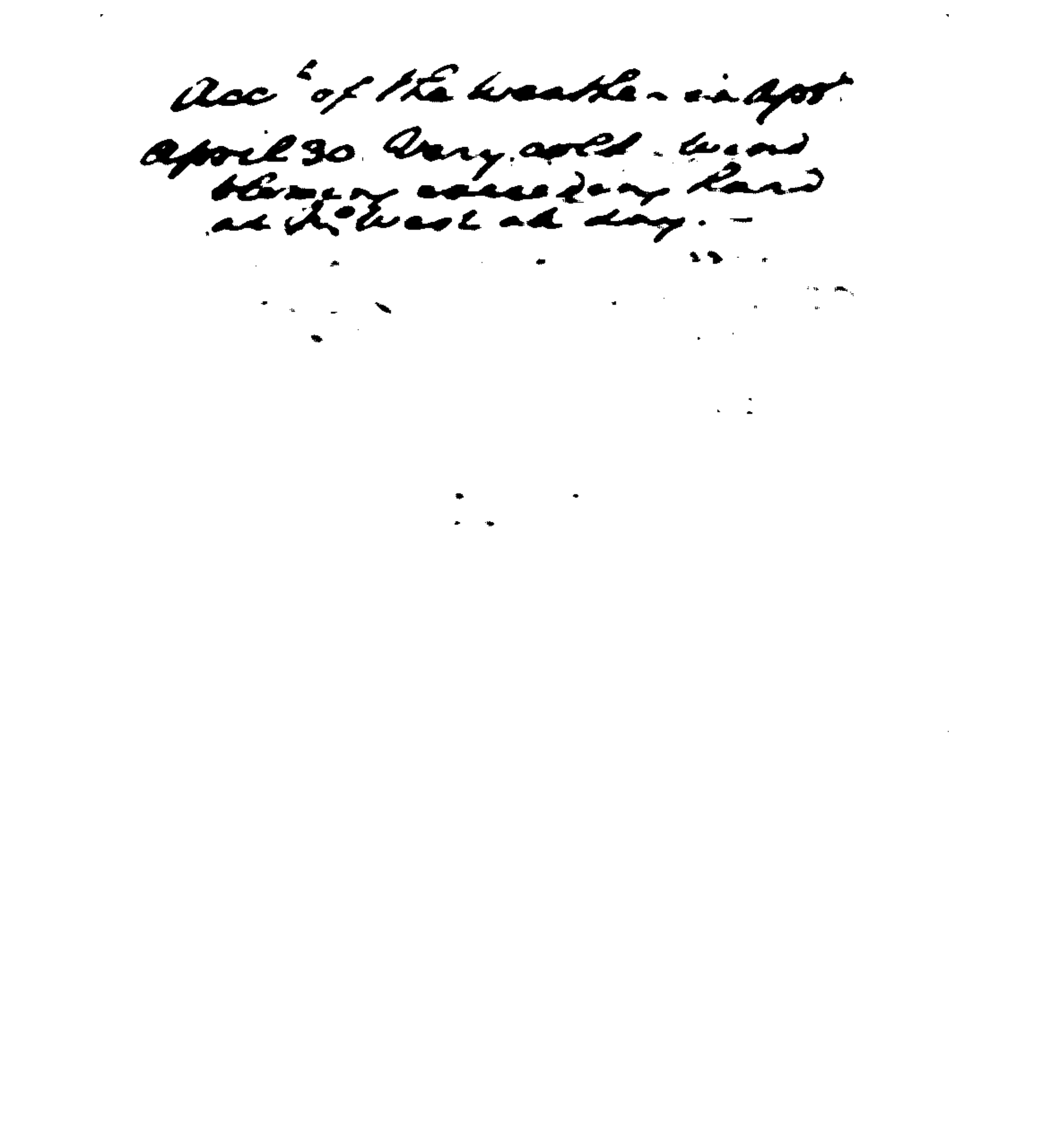


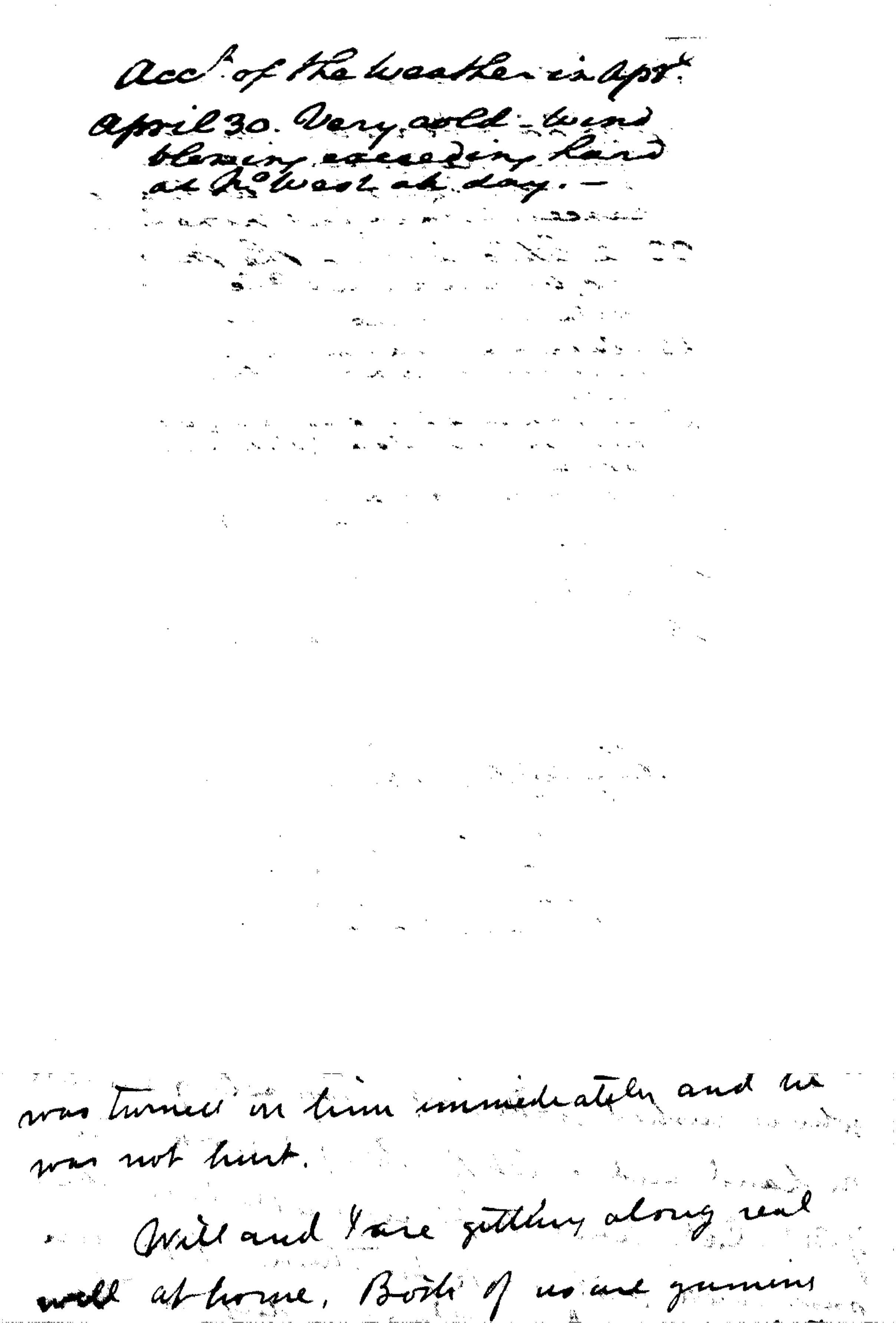
Fig.4.11. Median filter applied on Floyd-Steinberg error-diffusion output (window size 5×5)



Acc^t of the weather in Apr
April 30 Very cold wind

was turned on him immediately and he
was not hurt.
Will and I are getting along real
well at home. Both of us are

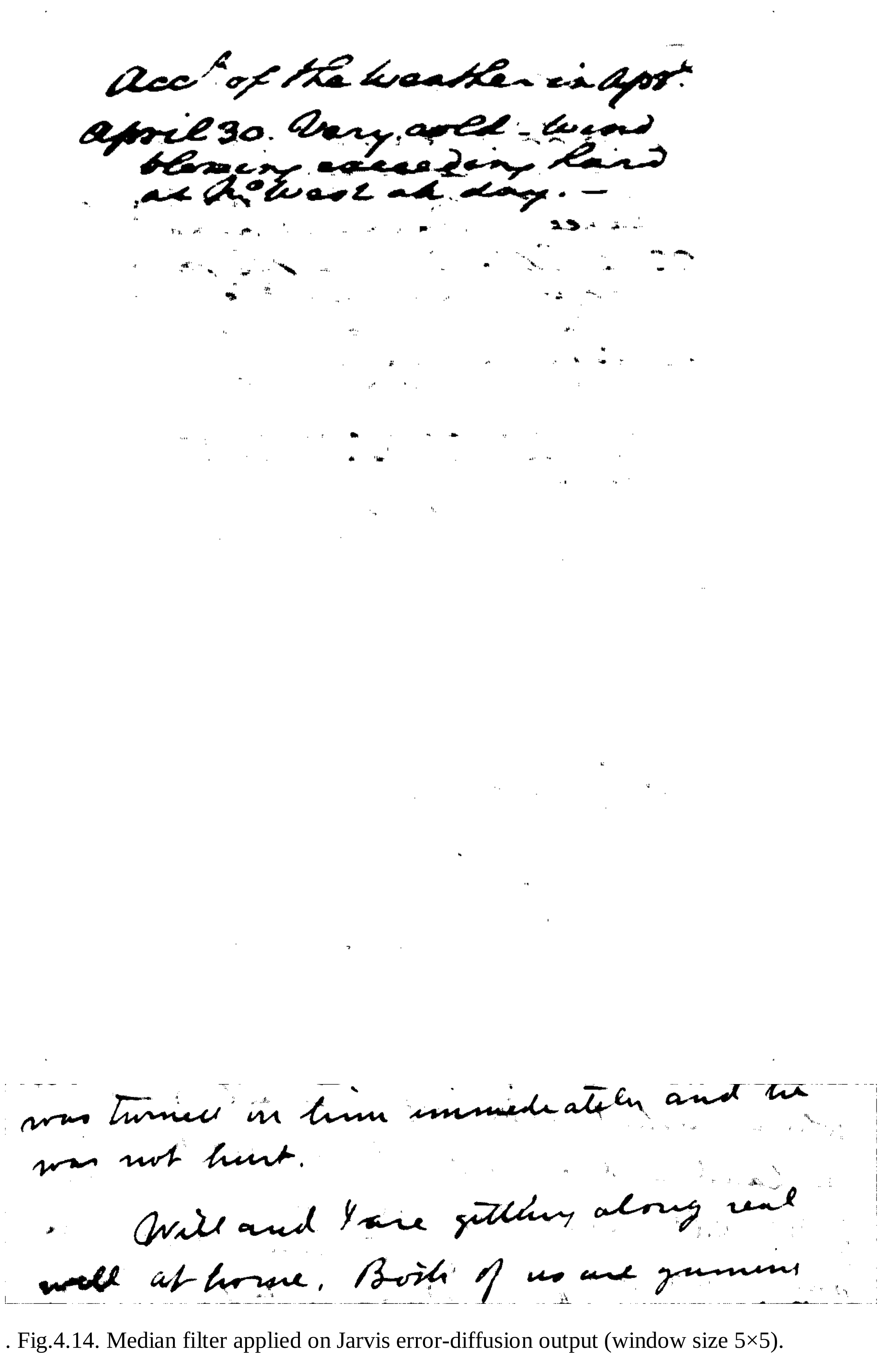
Fig..4.12 Median filter applied on Floyd-Steinberg error-diffusion output (window size 7×7)



Acct. of the weather in Apr.
April 30. Very cold - wind
blowing exceeding hard
at N° West all day. —

was turned on him immediately and he
was not hurt.
Will and I are getting along real
well at home, Both of us are gaining

. Fig.4.13. Median filter applied on Jarvis error-diffusion output (window size 3×3).



. Fig.4.14. Median filter applied on Jarvis error-diffusion output (window size 5×5).

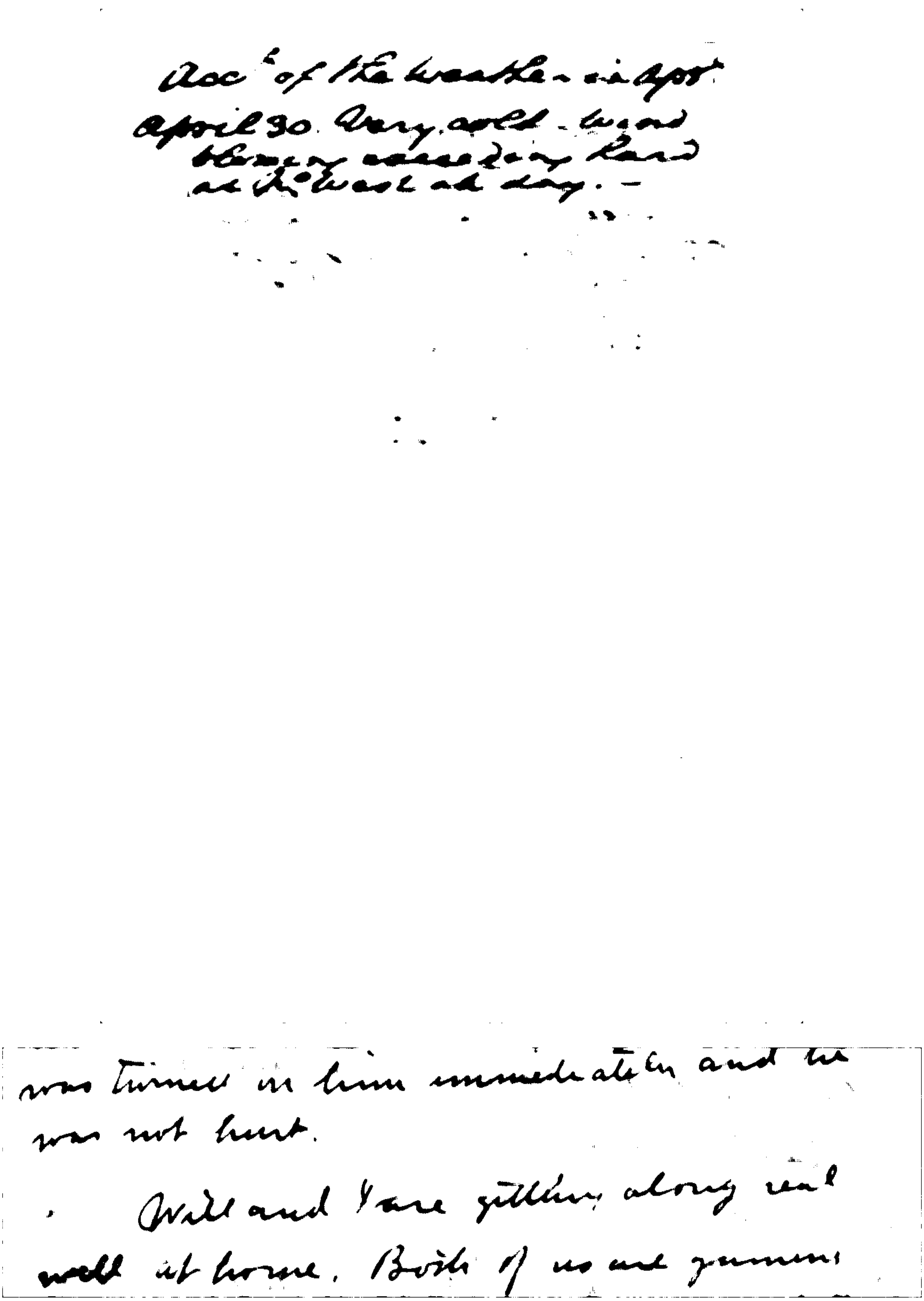
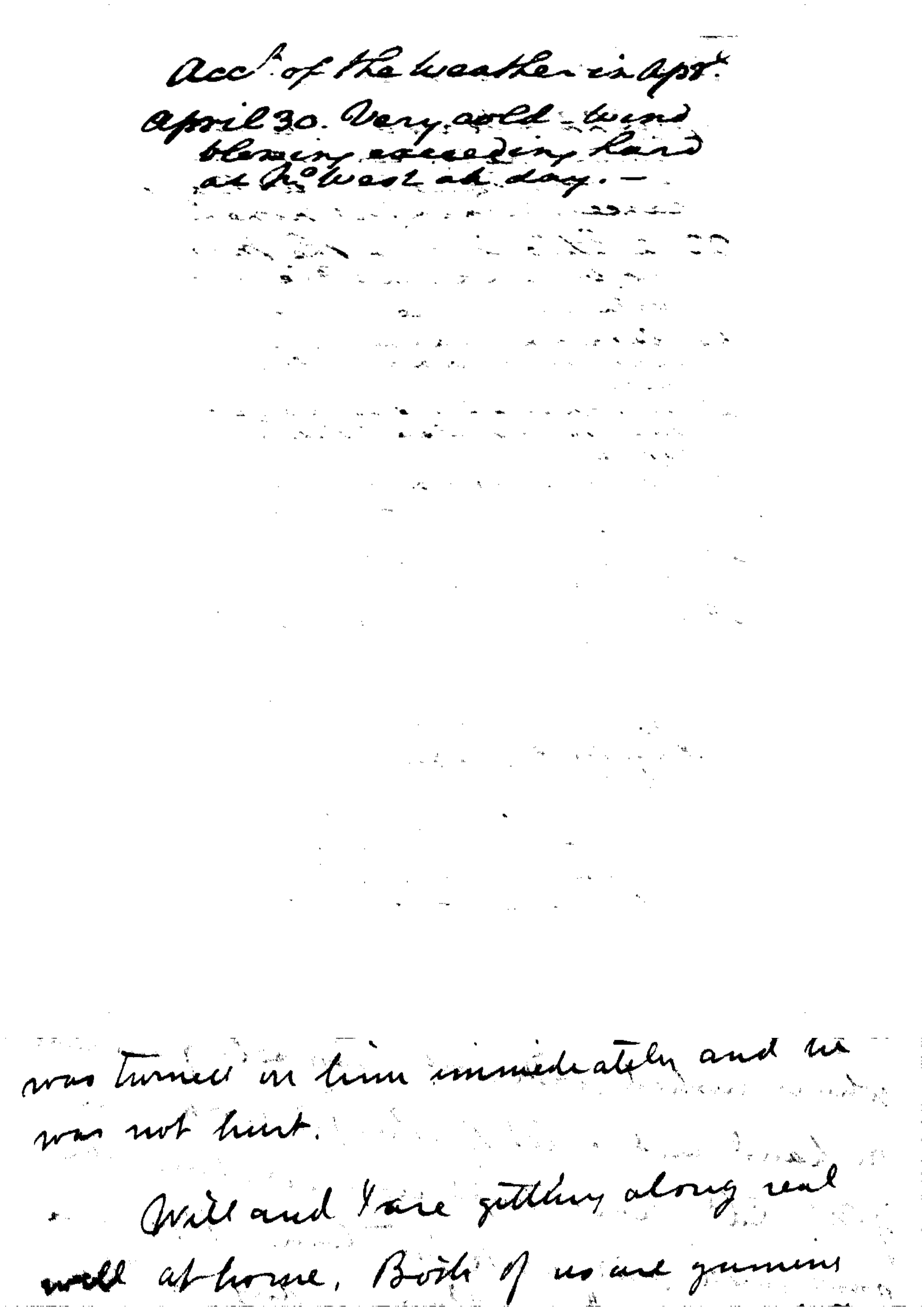


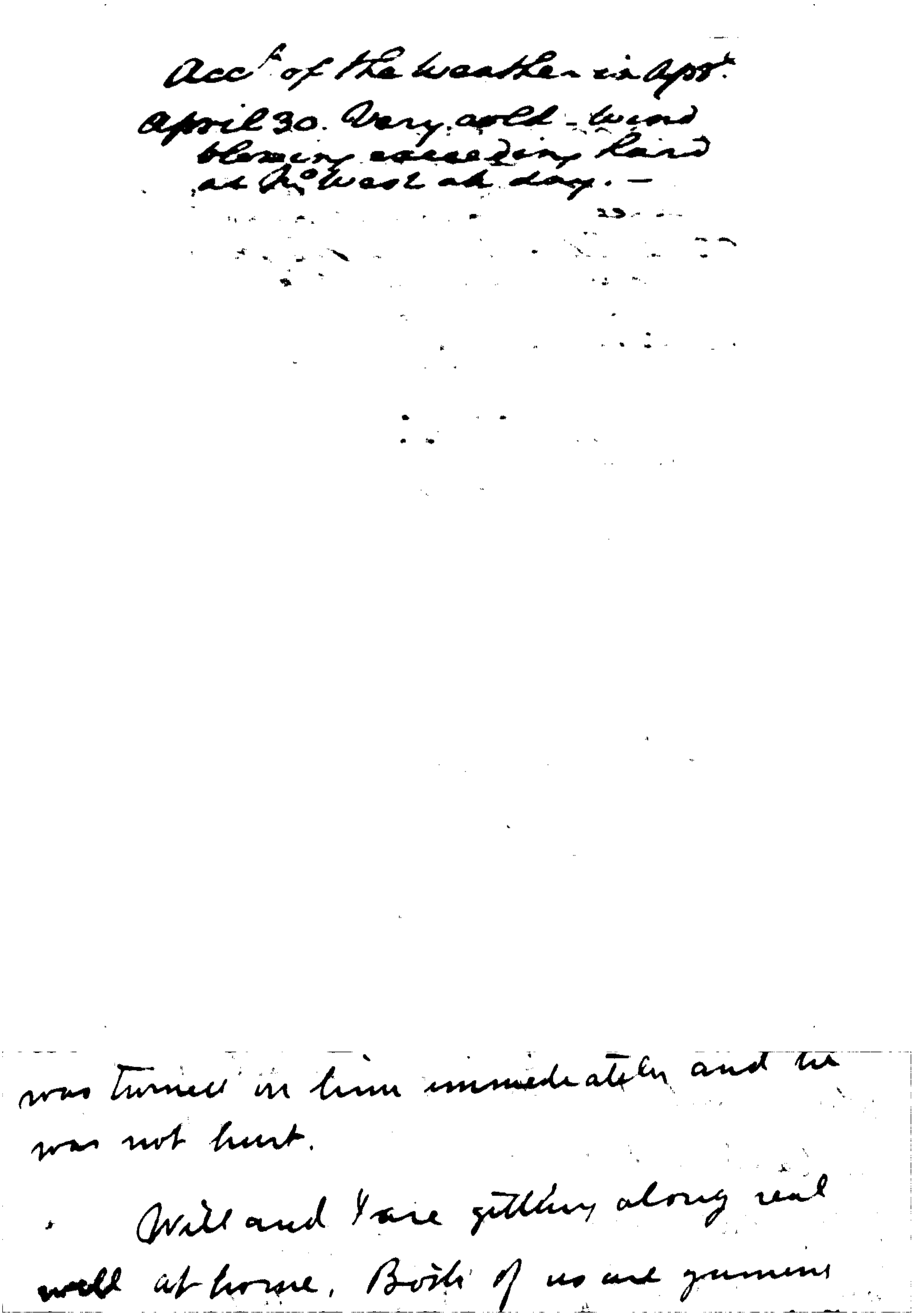
Fig.4.15. Median filter applied on Jarvis error-diffusion output (window size 7×7)



Acc.t of the weather in Apr.t
April 30. Very cold - wind
blowing exceeding hard
at N.o West all day. -

was turned on him immediately and he
was not hurt.
Will and I are getting along real
well at home. Both of us are gaining

Fig.4.16. Median filter applied on Stucki error-diffusion output (window size 3×3).



Acct of the weather in Apl.
April 30. Very cold - wind blowing exceeding hard at N°West all day. —

was turned in time immediately and he was not hurt.
Will and I are getting along real well at home. Both of us are gunning

Fig.4.17. Median filter applied on Stucki error-diffusion output (window size 5×5)

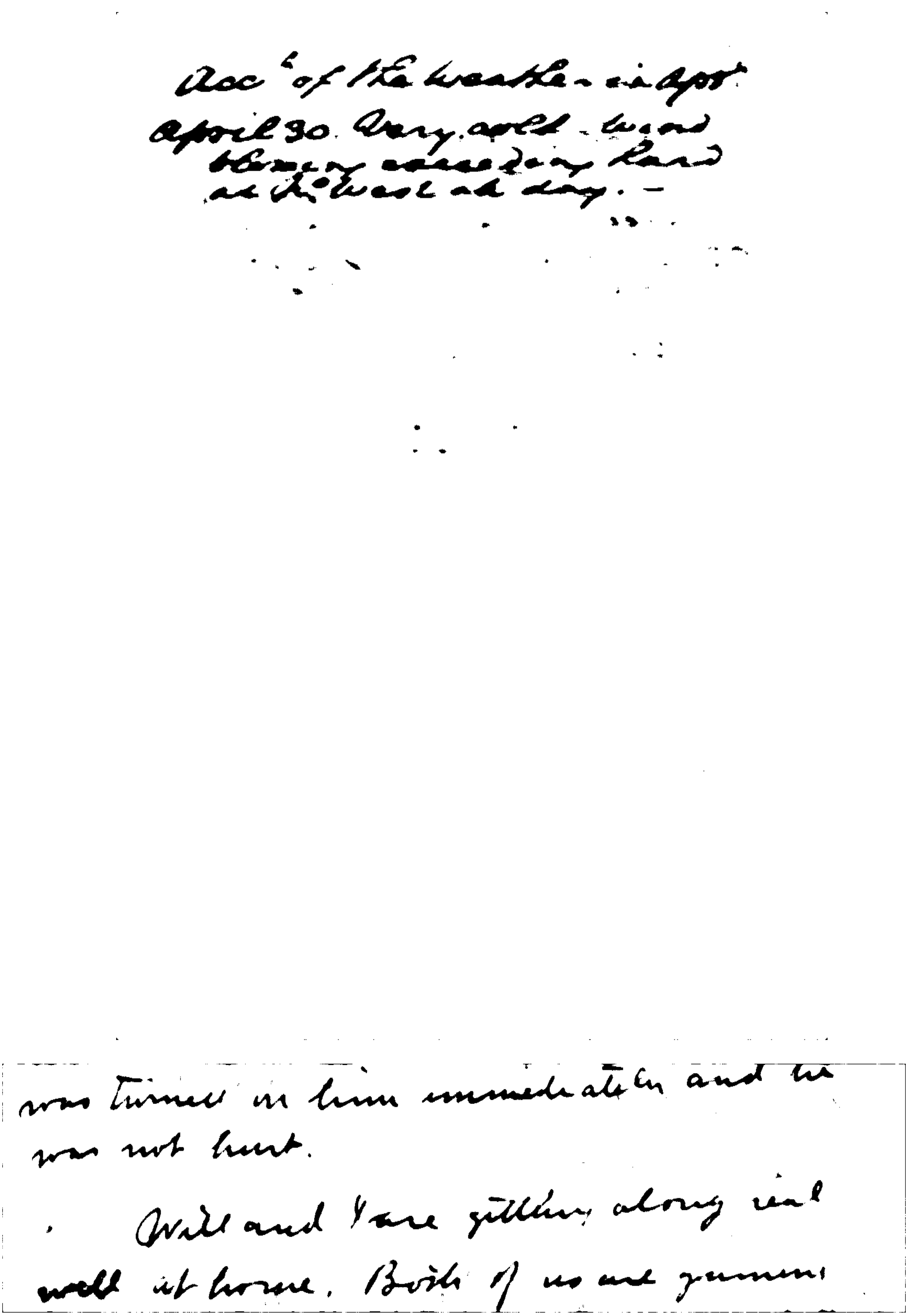
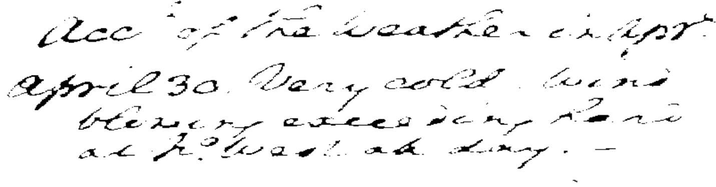


Fig.4.18. Median filter applied on Stucki error-diffusion output (window size 7×7)

As the window size is increased from 3×3 to 5×5 and 7×7 the background noise is reduced considerably but the text character gradually started getting broken. .



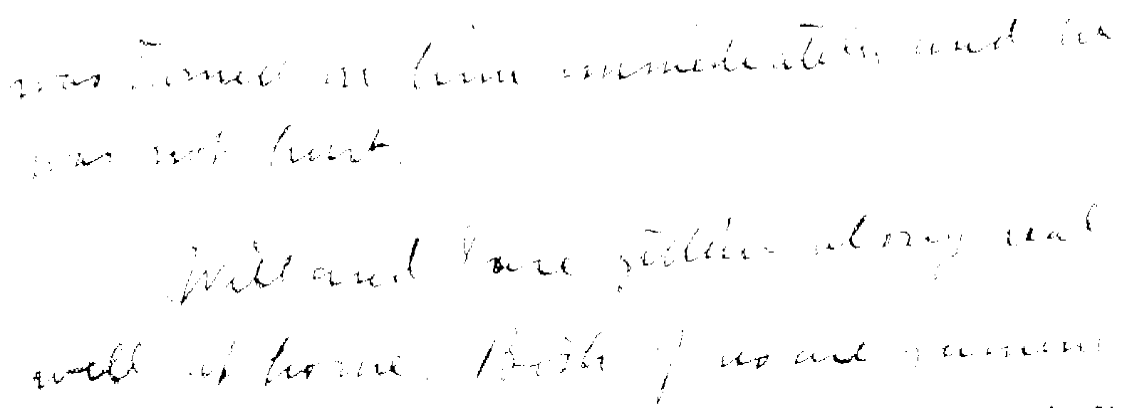


Fig.4.19. Maximum filter applied on Floyd-Steinberg error-diffusion output(window size 3×3).

Fig.4.20.Maximum filter applied on Floyd-Steinberg error-diffusion output (window size 5×5).

4.21. Maximum filter applied on Floyd-Steinberg error-diffusion output (window size 7×7).

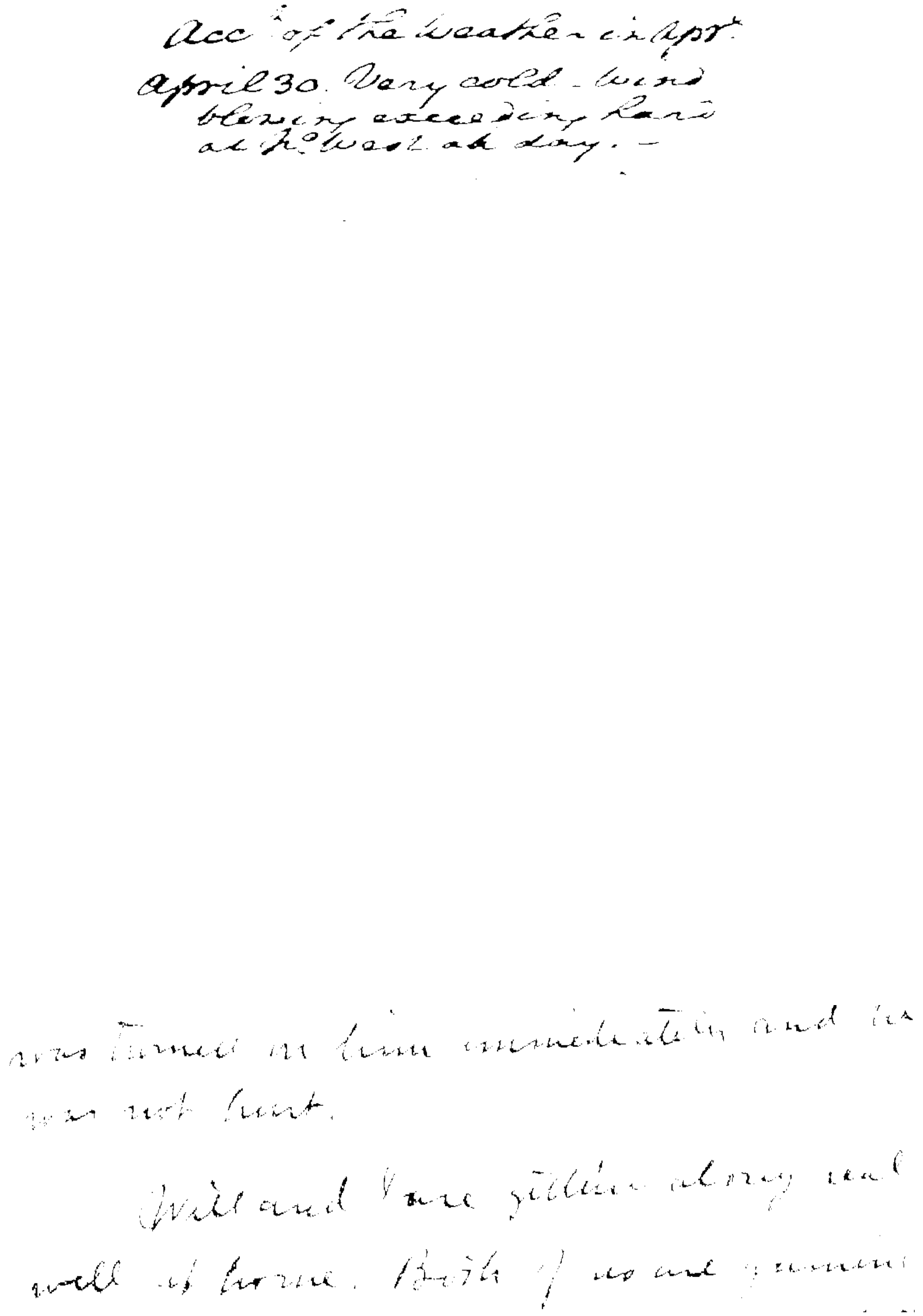


Fig.4.22. Maximum filter applied on Jarvis error-diffusion output(Widow size 3×3).

Fig.4.23. Maximum filter applied on Jarvis error-diffusion output (window size 5×5).

. Fig. 4.24. Maximum filter applied on Jarvis error-diffusion output (window size 7×7).

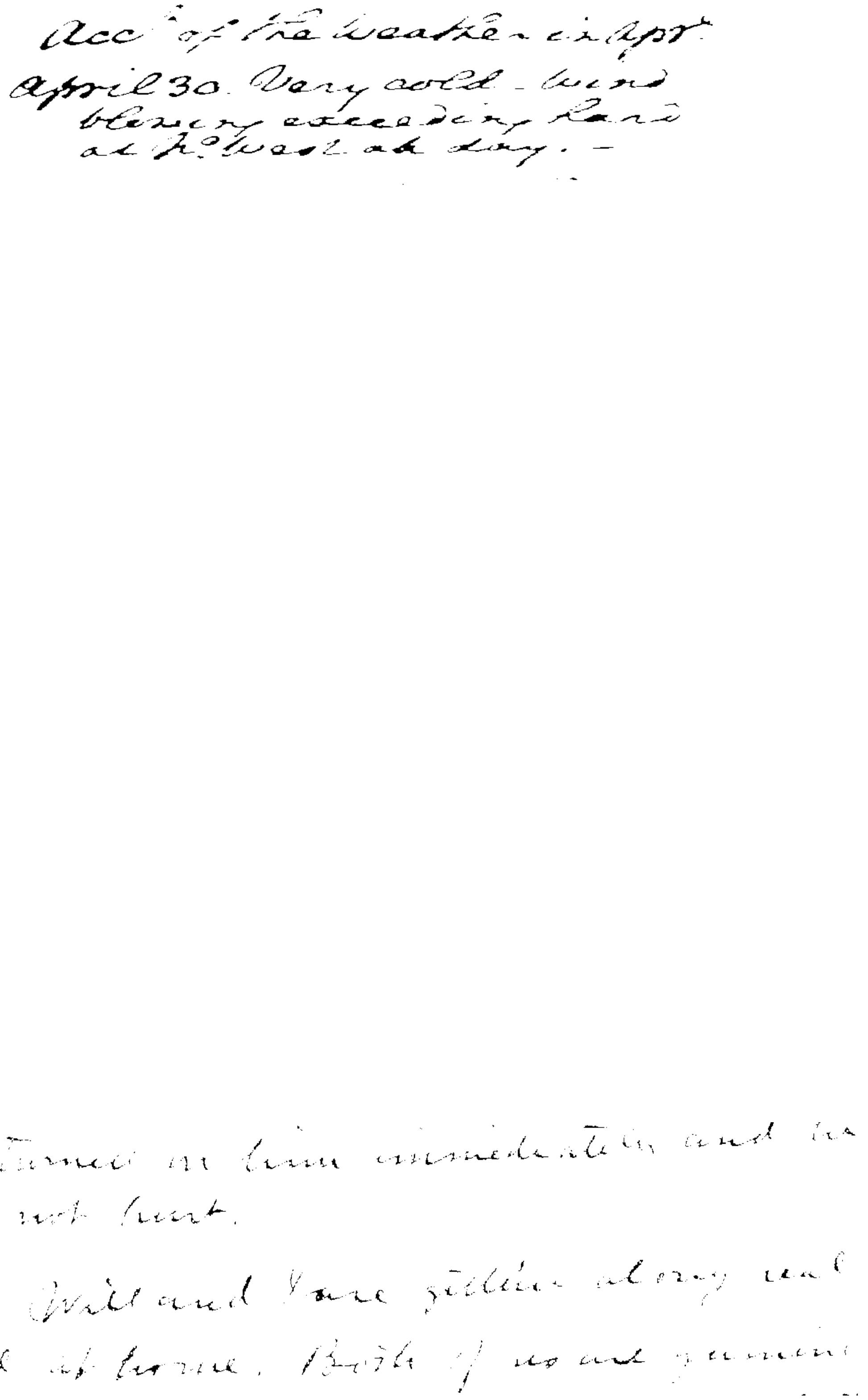


Fig.4.25. Maximum filter applied on Stucki error-diffusion output(window size 3×3)

Fig.4.26. Maximum filter applied on Stucki error-diffusion output (window size 5×5)

Fig..4.27. Maximum filter applied on Stucki error-diffusion output (window size 7×7)

In case of 3×3 window maximum filter is making the background noise reduction but few text portions are obscure and in case of 5×5 and 7×7 window barely any text is recognizable.

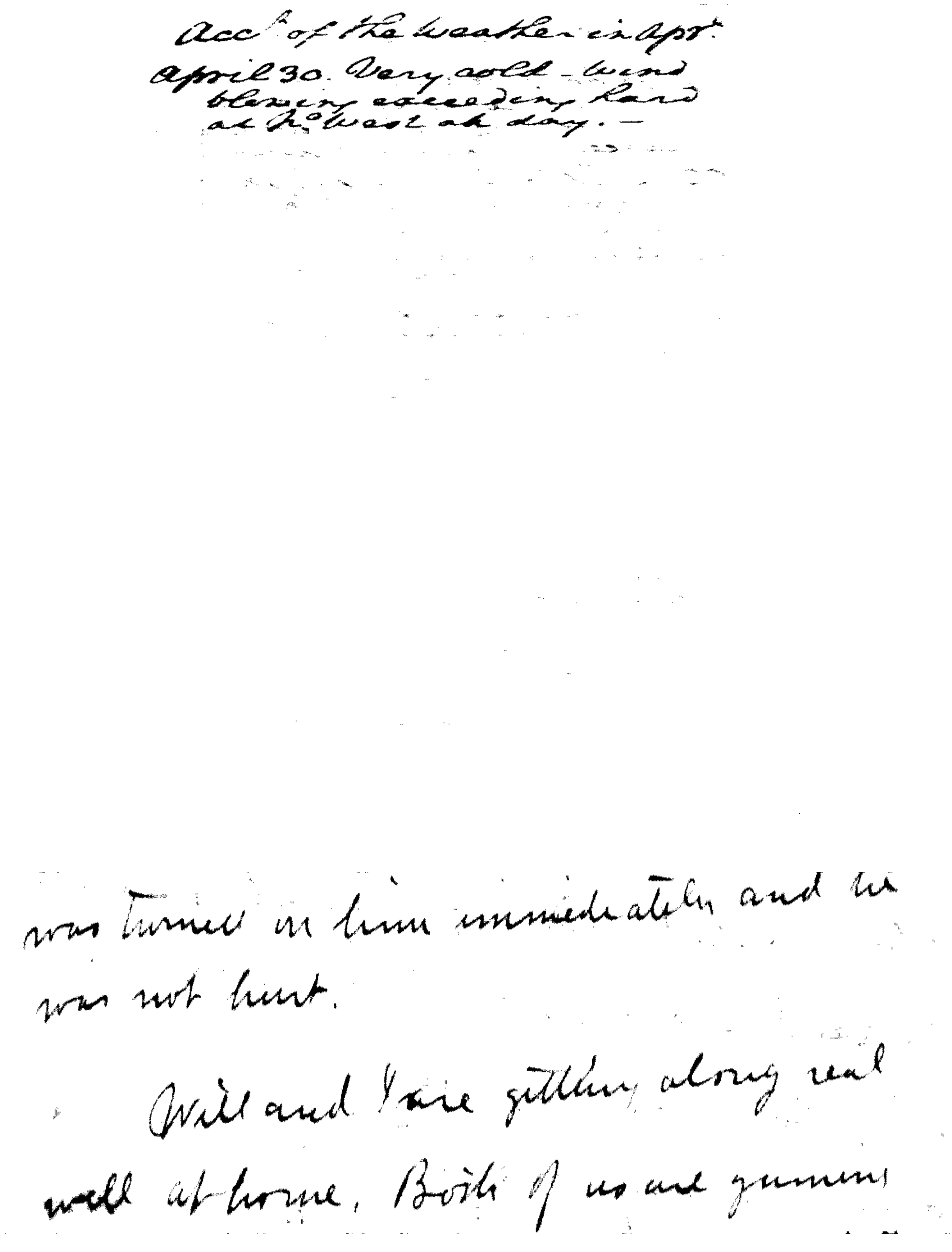
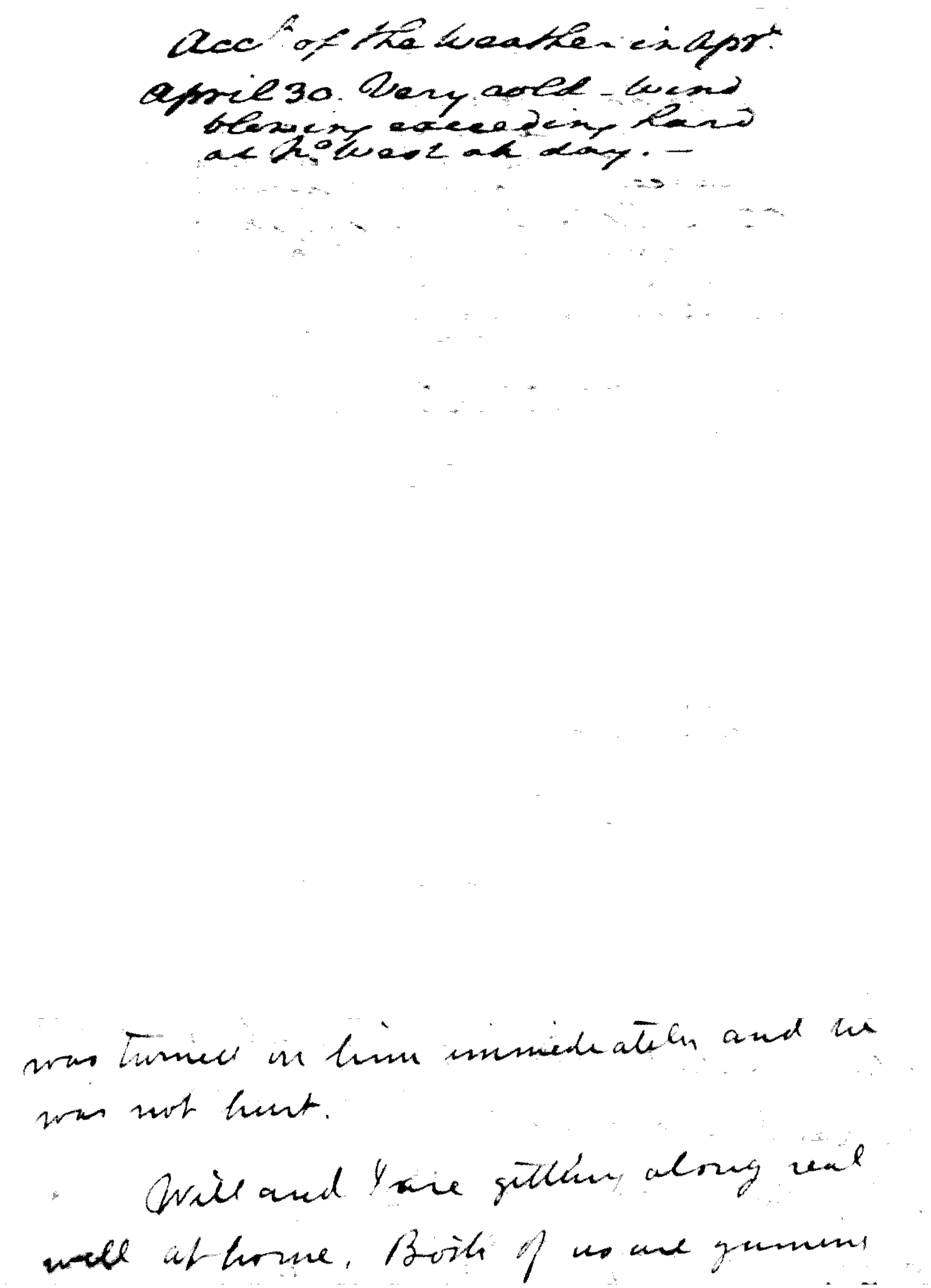
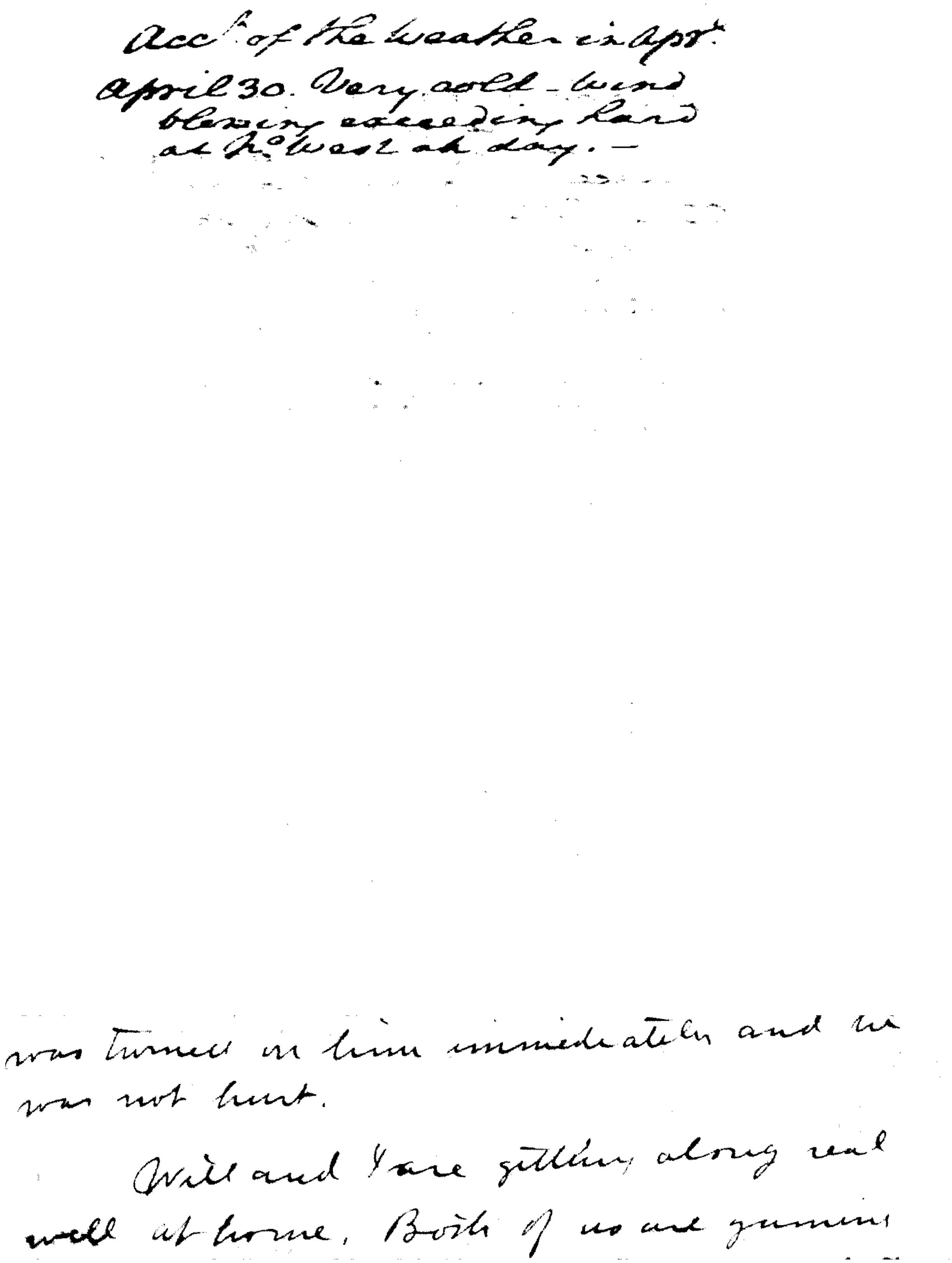


Fig.4.28. Rank order filter applied on Floyd-Steinberg error-diffusion output(window size 3×3)


Acct of the weather in Apr.
April 30. Very cold - wind
blowing exceeding hard
at No West all day. —

was turned on him immediately and he
was not hurt.
Will and I are getting along real
well at home. Both of us are gaining

Fig.4.29. Rank order filter applied on Jarvis error-diffusion output(window size 3×3)


Acct. of the weather in Apr.
April 30. Very cold - wind
blowing exceeding hard
at N. West all day. —

was turned on him immediately and he
was not hurt.
Will and I are getting along real
well at home. Both of us are gaining

Fig.4.30. Rank order filter applied on Stucki error-diffusion output(window size3×3)

This new rank order filter based on median filter is actually giving very good separation between text and background eliminating the noise. The text portion is also very prominent. Here 3×3 window size is used because bigger window sizes tend to break the text characters.

4.4. Comparative analysis

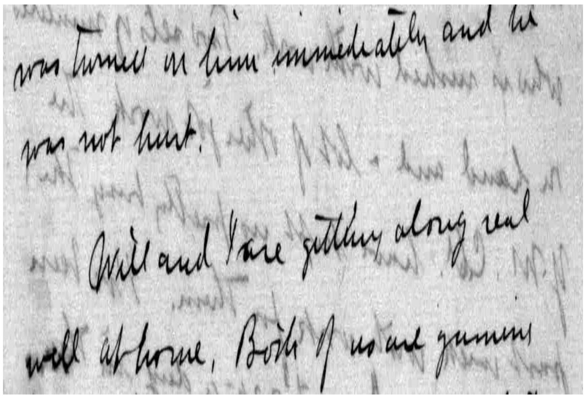
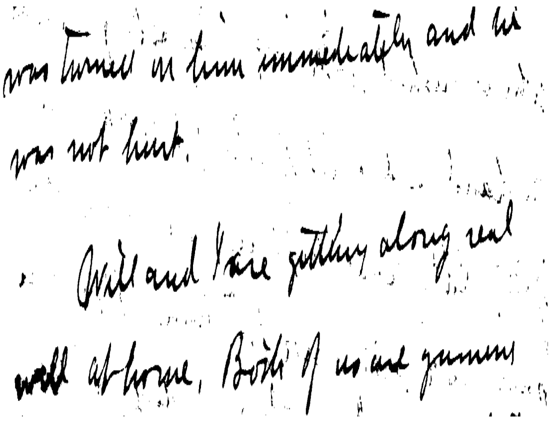
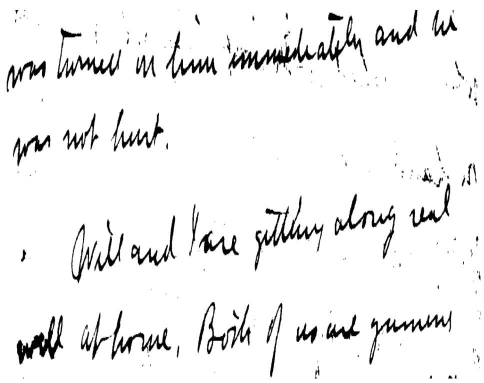


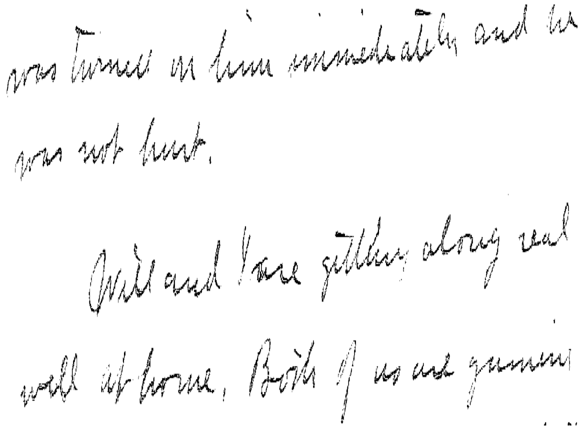
Fig.4.31.a. Original image



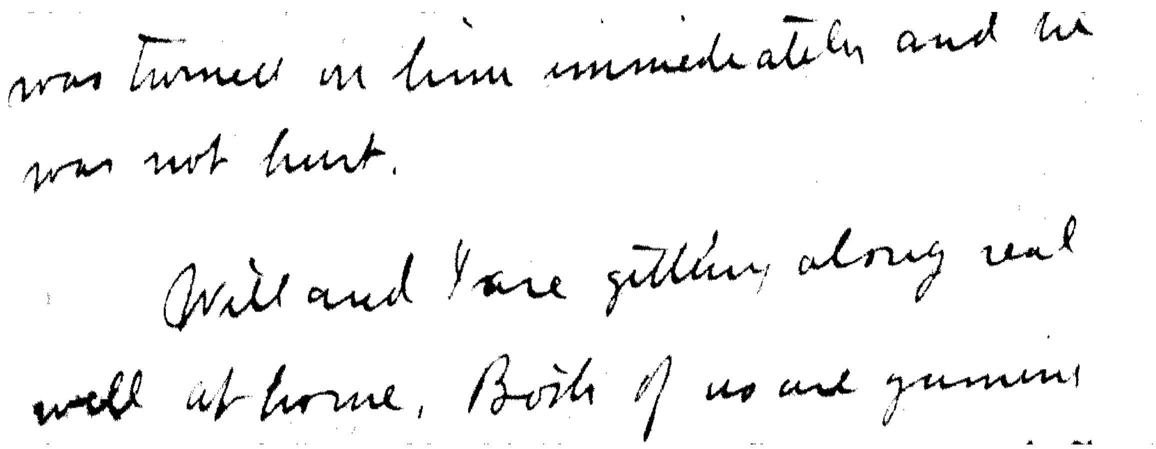
b. Image after applying Otsu's algorithm



c.Image applying Niblack's algorithm



d .Image after applying Sauvola's algorithm



d. Output of the halftone based method.

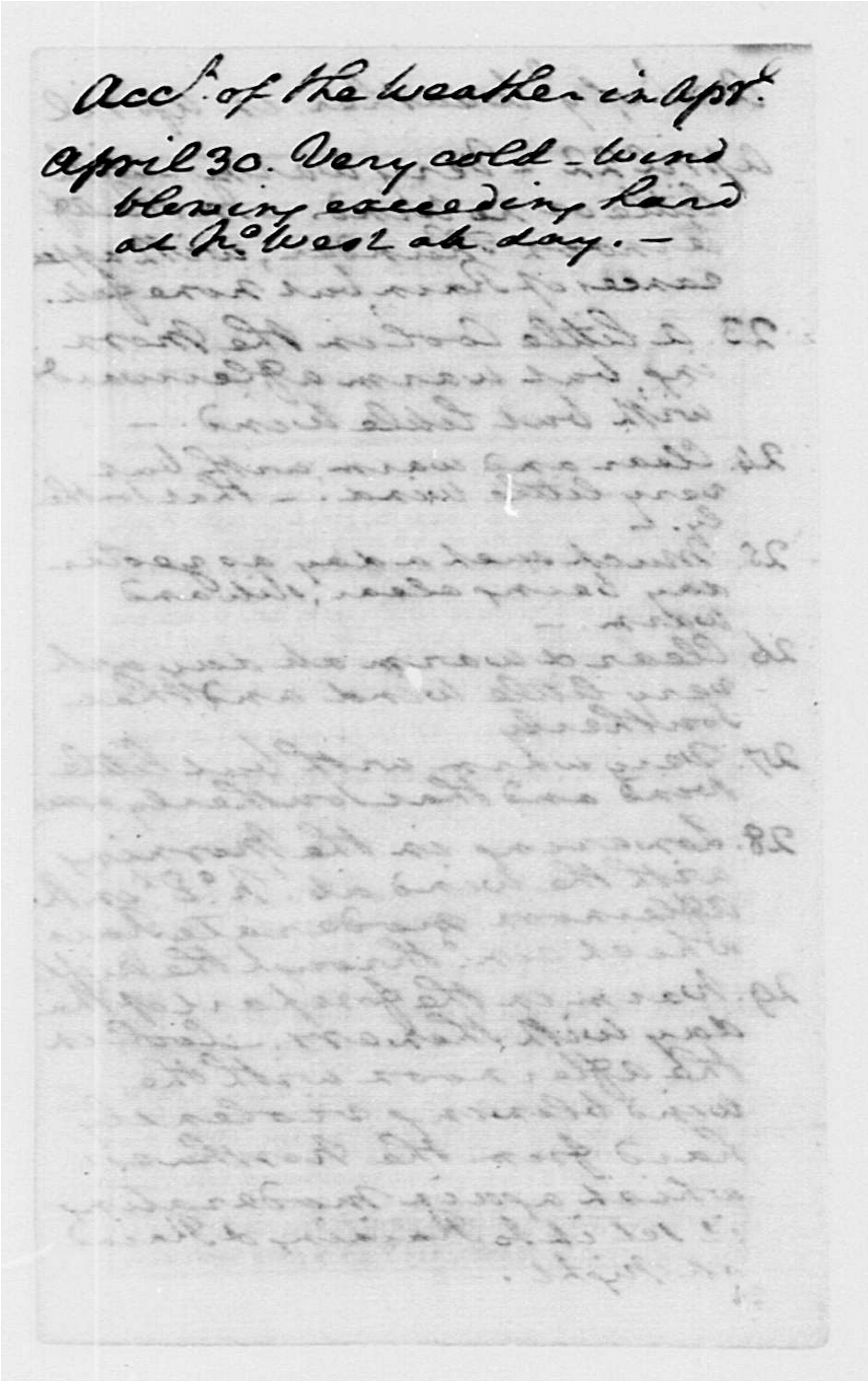

Accᵗ. of the weather in Aprˡ.
April 30. Very cold — wind
blowing exceeding hard
at No. West all day. —

Fig.4.32a. Original image

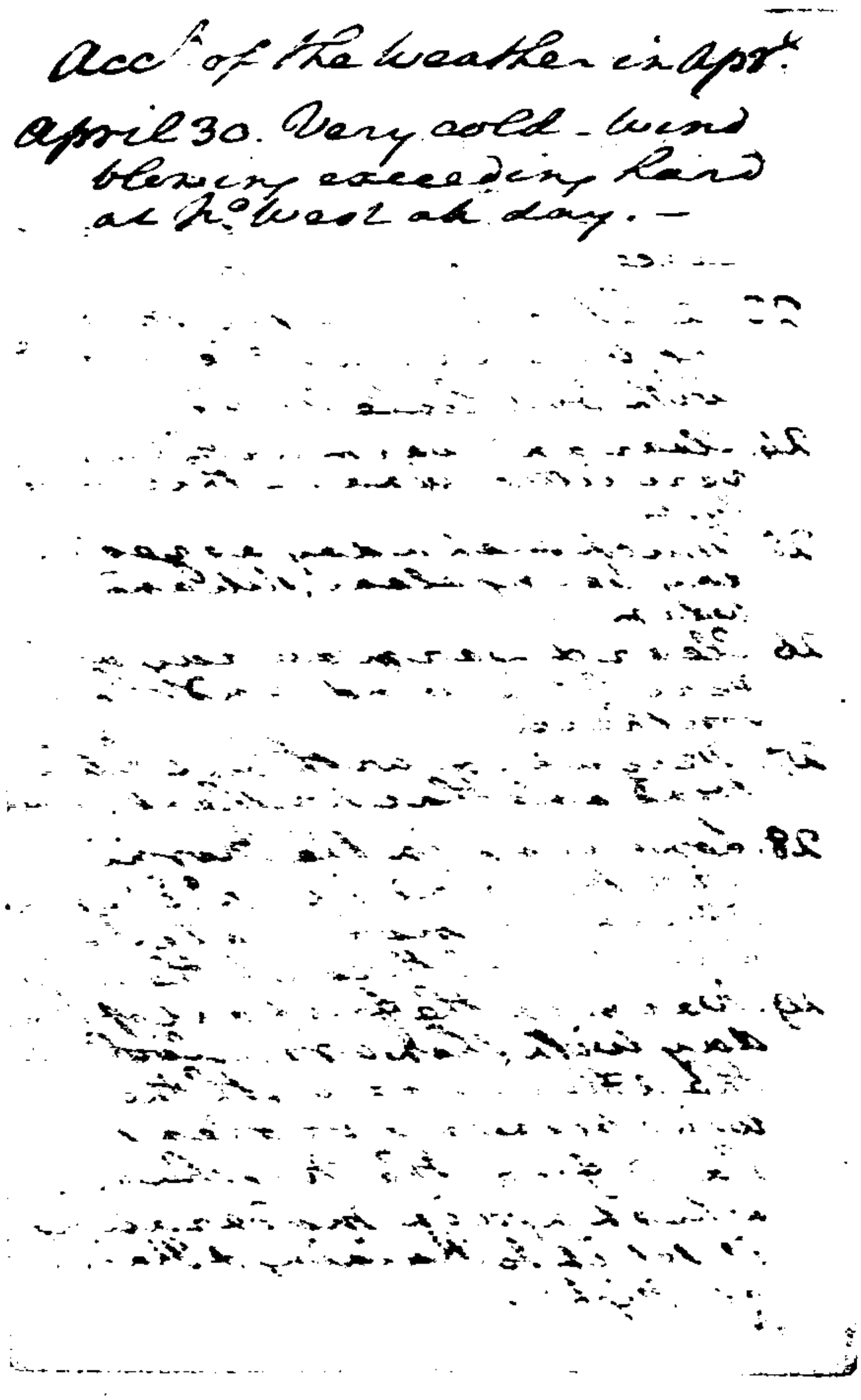

Acc^t of the weather in Apr.
April 30. Very cold - wind
blowing exceeding hard
at No West all day. —

Fig.4.32b. Image applying Niblack’s algorithm

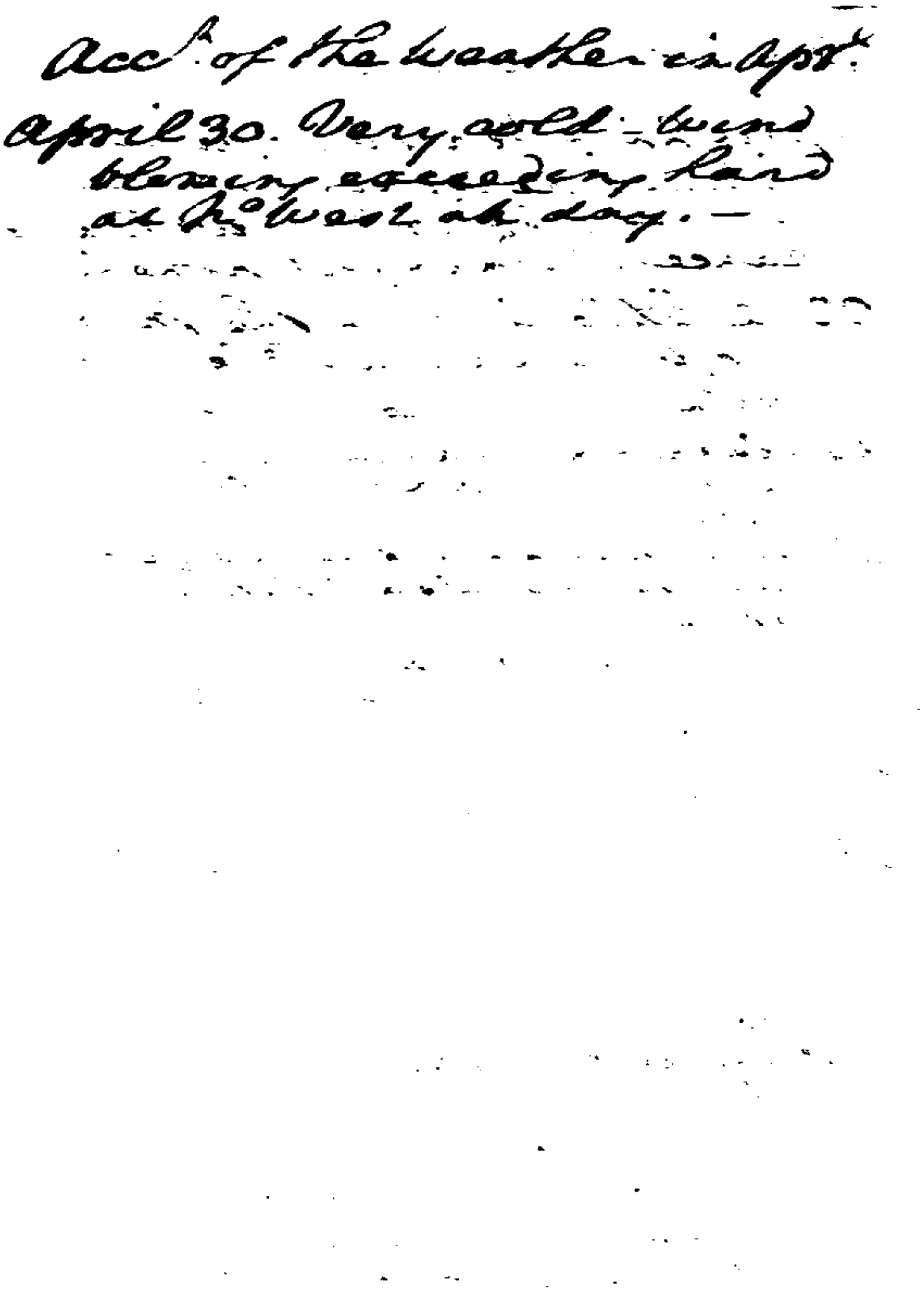

Acct. of the Weather in Apr.
april 30. Very cold — wind
blowing exceeding hard
at No West all day. —

Fig.4.32c.Image after applying Otsu’s algorithm

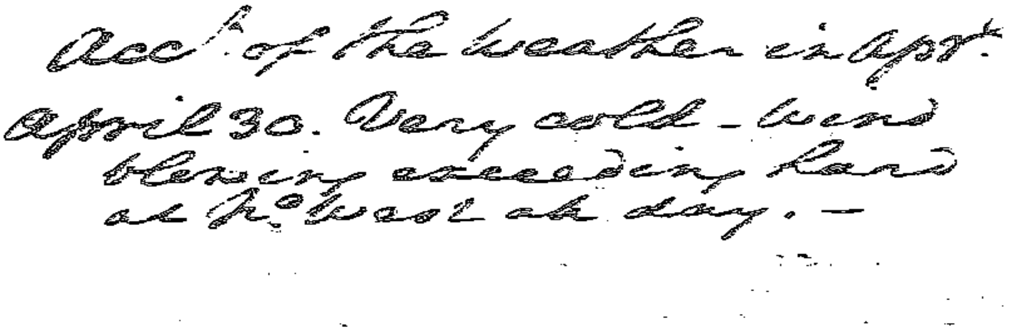
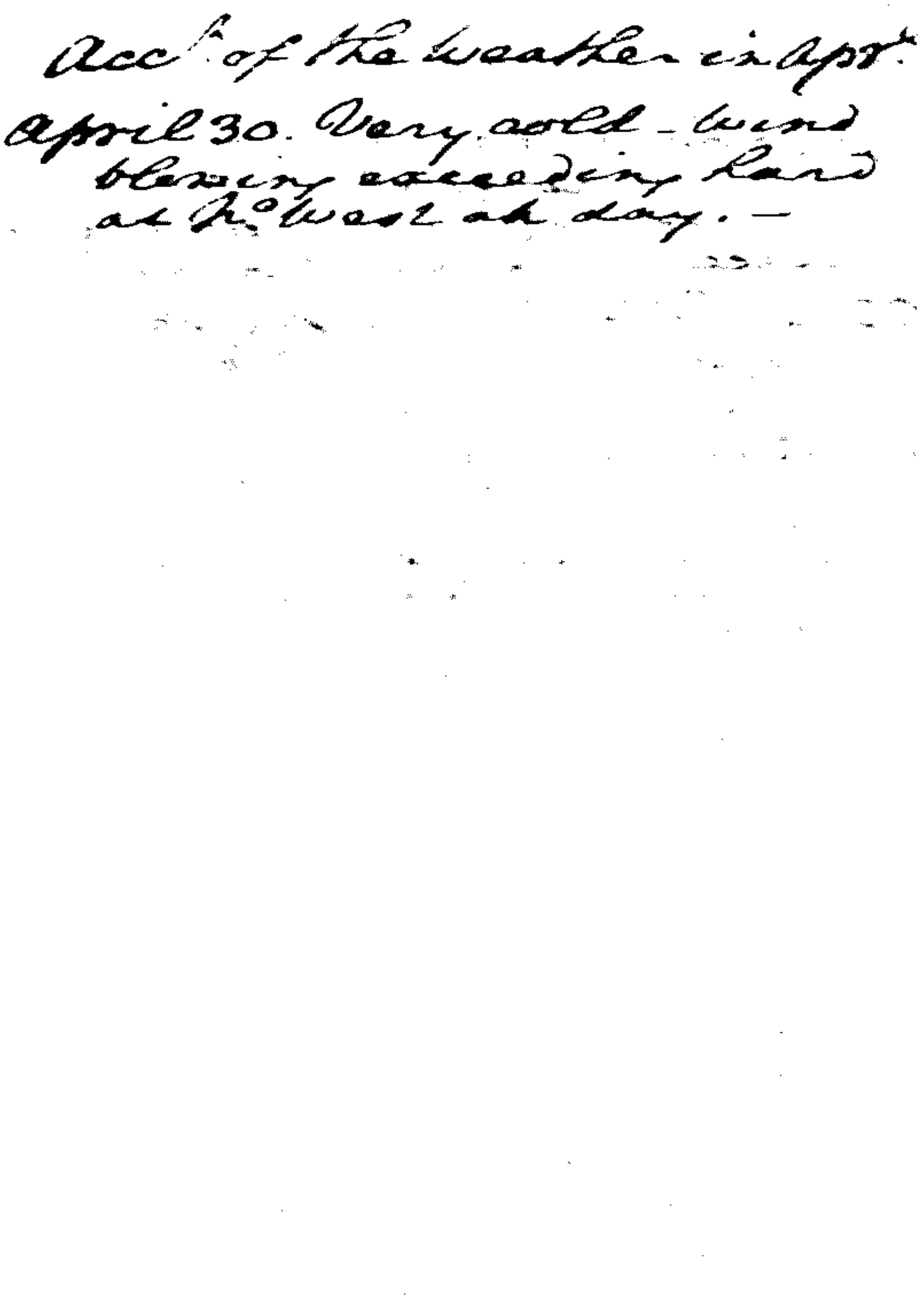

Acct. of the weather in Apr.
April 30. Very cold - wind
blowing exceeding hard
at N° West all day. —

Fig.4.32d. Image after applying sauvola's algorithm



Acct. of the weather in Apr.
April 30. Very cold - wind
blowing exceeding hard
at No. West all day. —

Fig.4.32e.Image after applying halftone based algorithm.

4.5. Conclusion

This chapter shows amongst the order statistics filter median, mean and one new rank order filter are giving satisfactory binary images from the halftone image. It is also found that compared to other standard algorithm like Otsu, Niblack, Sauvola et al it is giving better results in case of show-through affected document images. It can be seen from the above two DIBCO test images that after applying Otsu's algorithm there are still significant amount of background noise left. After applying Niblack's algorithm also there are substantial amount of noise left. By applying Sauvola et al the image is noise free but the texts are broken and hazy. When halftone based post processing is used the image is almost completely noise free and the text portion is very prominent.

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CHAPTER- 5

Concluding Remarks

5.1. Introduction

Digitization of document image makes document collection easy nowadays. This digitization process depends on (OCR) technique and for that we need a clear black and white image or binary image where the text portion is pure black and background is pure white. The reason is OCR technique performs better when provided with pure black and white image. But in case of show-through affected images the problem is that along with the recto portion's image verso portion's image gets overlapped or vice versa. It has been seen that over the years mostly some common algorithm like Otsu, Niblack, Sauvola et al or some method which are based on this methods are used for this purpose. It has been seen that a method based on Parker's method is also giving decent results. This method also uses Otsu algorithm.

Here the approach is to find out that whether halftone can have a role in this and if yes then develop the algorithm .Firstly two images are taken from DIBCO dataset which are substantially affected by show-through phenomenon. All the major halftoning algorithm like clustered dot ordered dithering, dispersed dot ordered dithering, error diffusion are run. Among all these algorithm error diffusion gives better results .Among error diffusion three most popular weight kernels Floyd-Steinberg, Jarvis, Stucki are used .It has been found that all of them giving good results in providing a binary image which can be further processed to get the noise free desired image. The results with different halftoning techniques been analysed here and found that the error diffusion technique is providing a better and clearer distribution of black and white dots. In the post processing step a neighbourhood based technique is applied. Here all the order statistics filter like median, maximum, minimum along with the mean filter and one new rank order filter is used. Among all this median, mean and the new order statistics filter gives better results. Lastly a comparative study is done where along with the standard algorithm like Otsu, Niblack, Sauvola the halftone based technique is compared. Here it has been found that the halftone based method is giving better output.

5.2. Major findings

The major findings from this work can be summarized as below;

1. Halftone based method can be applied to show-through affected images .

2. This method gives better result than any other standard algorithm like Otsu, Niblack, Sauvola et al in case of show-through affected images.

3. It does not require any user input like standard methods e.g. Niblack, Sauvola, etc.

4. Method is also less time consuming.

5. Method only needs one side of the document.

5.3. Future scopes

Some of the important future scope for the extension of this work can be listed as;

1. It can also be extended to color images.

2. It can be extended to more statistical based thresholding.

3. Inclusion of Artificial Intelligence towards segmentation based on halftone features is also possible.

5.4. Conclusion

Halftoning can be a major tool towards binarization. It may be a potential alternative to existing binarization techniques. It can be used for retrieval of voluminous document image affected by show through since it is less time consuming. It can be advantageous over some of the established techniques as it does not require any user input.

Appendix

All the established techniques and the new method used in this thesis are tested with the Matlab environment. All are given below.

Program 1: Otsu's method

```
a=imread ('C:\Users\Acer\Desktop\document.jpg');
b=rgb2gray(a);
level=graythresh(b);
c=im2bw(b,level);
imshow(c)
```

Program 2: Sauvola's method*

```
function s=sauv (im, window, k)
im = im2double(im);
mean = averagefilter(im, , window );
stdev=std2(im);
m_stdev=max(max(stdev));
T=mean.+ (1 - k*(1-stdev/m_stdev));
R = max(deviation(:));
s=im2bw(im,T);
```

Program 3: Niblack 's method*2

```
function n = nib(im, window, k)
im = im2double(im);
mean = averagefilter(im, , window );
stdev=std2(im);
n (im>mean + k * stdev) = 1;
```

Program 4:Method based on Parker et al

```
a=imread('C:\Users\Acer\Desktop\DIBCO\H_DIBCO2010_test_images\H05.jpg');
b=rgb2gray(a);
[m,n]=size(b);
ap=padarray(b,[4 4]);
for i=5:m
    for j=5:n
        x=ap(i-4:i+4,j-4:j+4);
        level=graythresh(x);
        f(i,j)=im2bw(b(i,j),level);
```

```
    end
end
imshow(f),title('locally dark pixels');
%identifying pixel near an edge
c=edge(b,'sobel');
for i=1:m
    for j=1:n
        if (c(i,j)==1)
            c1(i,j)=0;
        else
            c1(i,j)=b(i,j);
        end
    end
end
figure,imshow(c1),title('edge image');
fg=fspecial('gaussian',3,.01);
B=imfilter(c1,fg);
figure,imshow(B), title('smoothen image');
[m,n]=size(B);
ap1=padarray(B,[2 2]);
for i=3:m
    for j=3:n
        x1=ap1(i-2:i+2,j-2:j+2);
        a_st1(i,j)=std2(x1);
        l=graythresh(x1);
        f1(i,j)=l;
    end
end
a_st1=(a_st1./max(max(a_st1)));
for i=1:m
    for j=1:n
        f2(i,j)=im2bw(a_st1(i,j),f1(i,j));
    end
end
figure,imshow(f2),title('std dev image')
f3=1-f2;
[m,n]=size(f3); % where f2 is one of the images
e=zeros(m,n);
 for i=1:m
     for j=1:n
         if (f(i,j)==f3(i,j))
             e(i,j)=f(i,j);
         else
             e(i,j)=1;
         end
 end
 end
 figure,imshow(e)
```

Program 5: CDOD halftoning

```
function [out] = screen_9c(in)
[y,x] = size(in);
in2 = zeros(y+4,x+4); in2(3:y+2,3:x+2)=in;
out = zeros(size(in2));
screen = [20 9 11 20; 13 1 3 15; 20 7 5 20]/16;
for b = 1:2:y+1
  for a = rem(b,4):4:x+2-rem(b,4)
    out(b:b+2,a:a+3) = (in2(b:b+2,a:a+3)>=screen) + out(b:b+2,a:a+3);
  end
%  fprintf('\rDithering... %3d%% done',ceil(b/(y+1)*100))
end
fprintf('\n')
out=out(3:y+2,3:x+2);
imshow(screen_9c(imread('document.tif')));
```

Program 6: DDOD halftoning

```
function [out] = screen_16u(in)
[y,x] = size(in);
in2 = zeros(y+3,x+3); in2(1:y,1:x) = in;
out = zeros(size(in2));
% screen=[6 11 7 10; 14 1 15 4; 8 9 5 12; 16 3 13 2]/17;
screen = [8 11 7 10; 15 1 16 4; 6 9 5 12; 13 3 14 2]/17;
for b = 1:4:y
  for a = 1:4:x
    out(b:b+3,a:a+3) = (in2(b:b+3,a:a+3)>=screen) + out(b:b+3,a:a+3);
  end
  %fprintf('\rDithering... %3d%% done',ceil(b/y*100))
end
fprintf('\n')
out = out(1:y,1:x);
imshow(screen_16u(imread('document.tif')));
```

Program 7: Error Diffusion using Floyd-Steinbergh kernel

```
function [out, qn, k] = errdiff(in, fc, l, dir, v)
if nargin<2                                   % default to Floyd-Steinberg
  fc=[0 -99*16 7; 3 5 1]/16;
 end
[ri,ci]=size(in);
[rm,cm]=size(fc);
[r0,c0]=find(fc==-99);                                % find origin of error filter
fc(r0,c0)=0;
rm=rm-1; cm=cm-1;
inpad=zeros(ri+rm,ci+cm);                     % modified input image
```

```
inpad(r0:r0+ri-1,c0:c0+ci-1)=in;
out=zeros(ri,ci); qn=out;
sp=1; ep=ci; step=1;                    % for direction changing
r0=r0-1; c0=c0-1;
for y=1:ri
  for x=sp:step:ep
    inpix=inpad(y+r0,x+c0);
    outpix=(inpix+l*in(y,x))>=0.5;
    out(y,x)=outpix;
    qerr=outpix-inpix;
    qn(y,x)=qerr;
    inpad(y:y+rm,x:x+cm)=inpad(y:y+rm,x:x+cm)-qerr*fc;
  end
  if dir==-1
    step=-step; temp=ep; ep=sp; sp=temp;
    fc=fc(:,cm+1:-1:1); end
  if v
   % fprintf('\rDithering... %3d%% done',round(y/ri*100)),
   end
end

if v
  fprintf('\n')
end

if nargout==3
  xp=out(:)-0.5-qn(:);
  k=sum(abs(xp))/(2*sum(xp.^2));
end
function [y,q,k] = floyd(in)
[y,q,k] = errdiff(in);
imshow(floyd(imread('doc.tif')));
```

Program 8: Error Diffusion using Jarvis kernel

```
function [y,q,k] = jarvis(in)
[y,q,k] = errdiff(in,[0 0 -99*48 7 5; 3 5 7 5 3; 1 3 5 3 1]/48);
imshow(jarvis(imread('doc.tif')));
```

Program 9: Error Diffusion using Stucki kernel

```
function [y,q,k] = stucki(in)
[y,q,k] = errdiff(in,[0 0 -99*42 8 4; 2 4 8 4 2; 1 2 4 2 1]/42);
imshow(stucki(imread('doc.tif')));
```

*** The halftoning algorithm were implemented using the Halftoning Toolbox for Matlab (developed by Vishal Monga and Niranjan Damera-Venkata, University of Texas).

Program 10: Neighborhood based postprocessing using mean filter

```
a=imread('C:\Users\Acer\Desktop\Sourav MTech Thesis120605163.5.16\HT images\stck1.jpg');
b=im2bw(a);
[m,n]=size(b);
ap=padarray(b,[2 2]);
for i=3:m
   for j=3:n
      x=ap(i-2:i+2,j-2:j+2);
      f(i,j)=mean2(x);
   end
end
imshow(f);
f1=im2bw(f>.4);
f2=f1(3:m,3:n);
imshow(f2);
imwrite(f2,'C:\Users\Acer\Desktop\Sourav MTech Thesis120605163.5.16\HT images\stck1_pp_mean455.tif')
```

Program 11: Neighborhood based postprocessing using maximum filter

```
a=imread('C:\Users\Acer\Desktop\Sourav MTech Thesis100605163.5.16\HT images\stck2.tif');
c=ordfilt2(a,25,ones(5,5));
imwrite(c,'C:\Users\Acer\Desktop\Sourav MTech Thesis100605163.5.16\HT images\stck2_pp_max55.tif')
```

Program 12:Neighborhood based postprocessing using minimum filter

```
a=imread('C:\Users\Acer\Desktop\Sourav MTech Thesis100605163.5.16\HT images\stck2.tif');
c=ordfilt2(a,1,ones(3,3));
imwrite(c,'C:\Users\Acer\Desktop\Sourav MTech Thesis100605163.5.16\HT images\stck2_pp_max55.tif')
```

Program 13:Neighborhood based postprocessing using median filter

```
a=imread('C:\Users\Acer\Desktop\Sourav MTech Thesis100605163.5.16\HT images\stck2.tif');
c=medfilt2(a,[3 3]));
imwrite(c,'C:\Users\Acer\Desktop\Sourav MTech Thesis100605163.5.16\HT images\stck2_pp_max55.tif')
```

Program 14: Neighborhood based postprocessing using new rank order filter

```
a=imread(‘halftone image.tif’);
f=[1 1 1;1 0 1;1 1 1];
```

```
f_c=imfilter(double(a),f);
f_c1=ordfilt2(f_c,5,[0 1 0; 1 0 1; 0 1 0]);
f_c2=im2bw(f_c>1);
imwrite(......);
```

Program 15: Halftone based show-through removal algorithm

```
a=imread('doc.tif');
a1=rgb2gray(im2double(a));
a1_h=errdiff(a1);
f=[1 1 1;1 0 1;1 1 1];
f_c=imfilter(double(a1_h),f);
f_c1=ordfilt2(f_c,5,[0 1 0; 1 0 1; 0 1 0]);
f_c2=im2bw(f_c>1);
imwrite(......);
```