Automatic Dodging of Aerial Images

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Abstract: We present an automated approach for the dodging of images, with which we edit digital images as it is usually done with analogue images in dark-rooms.

Millions of aerial images of all battle fields were taken during the Second World War. They were intensively used, e.g. for the observation of military movements, the documentation of success and failure of military operations and further planning. Today, the information of these images supports the removal of explosives of the Second World War and the identification of dangerous waste in the soil. In North Rhine-Westphalia, approximately 300.000 aerial images are scanned to handle the huge amount of available data efficiently. The scanning is done with a gray value depth of 12 bits and a pixel size of 21 μm to gain both, a high radiometric and a high geometric resolution of the images. Due to the photographic process used in the 1930s and 1940s and several reproductions, the digitized images are exposed locally very differently. Therefore, the images shall be improved by automated dodging.

Global approaches mostly returned unsatisfying results. Therefore, we present a new approach, which is based on local histogram equalization. Other methods as spreading the histogram or linear transformations of the histogram manipulate the images either too much or not enough. For the implementation of our approach, we focus not only on the quality of the resulting images, but also on robustness and performance of the algorithm. Thus, the technique can also be used for other applications concerning image improvements.

1 Introduction

1.1 Allied images for the disposal of explosives of the Second World War

Millions of aerial images of all battle fields were taken during the Second World War (WWII). Especially Great Britain already started taking photographs of parts of Germany even before the beginning of the Second World War. During the war the organization of the aerial reconnaissance was constantly improved (Babington Smith, 2004). The number of images increased rapidly (LUA NRW, 2006).

The aerial images were intensively used, e.g. for the observation of military movements, the documentation of success and failure of military operations or the planning of further strategies. The films were developed in the field immediately after landing. A courier delivered them to the

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headquarters, often only a few hours after the landing of the reconnaissance plane (Stanley, 1981).

Today, these images support the removal of explosives of the Second World War or the identification of dangerous waste in the soil. North Rhine-Westphalia (NRW) has two bomb disposal services which identify, detect, remove and destroy not yet exploded bombs and other munitions. The first step of the removal of bombs is image interpretation. The services archive almost 300,000 allied images. The photo interpreter and geodesists identify in these images bombed areas, signatures of unexploded bombs and of military infrastructure and reference this data. Detection and removal units complete the job in the field.

1.2 Digitization of the archive of analog allied images

Up to now analogue photo copies have been used for the image interpretation. The image interpretation task is done separately for each site. For each multi-temporal image interpretation from 10 up to several hundreds of images have to be analyzed. Therefore the explosive disposal units put a high effort in managing the analogue archives at the moment. This effort will increase when additional images will be available from recently opened archives (Carls & Müller, 2007).

In the future only digital images will be used. All sites will be interpreted from digital images. Therefore all images have to be digitized with high accuracy resulting from high demands of interpretation quality for the bomb disposal task, i.e. a high radiometric contrast to identify small holes in the bare soil which result from the penetration of the unexploded bombs, and a high geometric accuracy to get precise coordinates of possible places of unexploded bombs.

In addition to the demands resulting from the task of bomb disposal, additional demands result from economical aspects: no human interaction should be needed for the scanning of each image nor for the improvement of the scanned images. These efforts point out that a high degree of automation of the process is needed. The large amount of images makes a priori investigations sensible and economical interesting.

1.3 Overview of the rest of the paper

In the following we will describe the scanning process. In chapter 3 we will report on several tests of image improvement methods which use intuitive and commercially available algorithms. Afterwards in chapter 4 we will present results and demonstrate some properties. This paper closes with a short summary and an outlook on the further work which has to be done in the scanning project.

2 Automated scanning of allied images of the WWII

2.1 Scanning overview

In the 1990s Germany got access to images from the British archive of allied aerial images, which nowadays is hosted at TARA[4]. Back then hundreds of boxes with cut aerial images were brought to Germany. Each of the borrowed images is a copy in an unknown series of copies of

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[4] The Aerial Reconnaissance Archives (TARA) at Keele University, www.evidenceincamera.co.uk, last visit: 1.5.2007

the original photographs. These copies survived somehow the confusion during and after WWII. These images were reproduced on film rolls and were archived in Germany again. Since then, they have been used to generate analogue photos for manual image interpretation of the bomb disposal units for the last 15 years. During the photographic reproduction process on paper a line-based photographic dodging was performed in a dark-room. The exposure time was calculated from the brightness of each reproduced image line.

For the scanning project the existence of the film rolls is a big benefit, because the rolls allow automatic scanning by a photogrammetric scanner. We use a unique label found on each image to identify each image on the film roll and scan the images with 21µm resolution in 12 bits. Although the image is scanned with 12 bits, storage of the data follows in 16 bits. To avoid time-consuming and individual scan settings for each film and each image resp., only one set of parameters is used during the scan process for efficient scanning. That is why in most cases the overall image quality of the original scans is inadequate. Figure 1 gives an impression of the quality of the majority of the scanned images.

This scanning result does obviously not allow a reliable interpretation. Thus, an algorithm for image improvement has to be found. The following demands have to be satisfied by the resulting images:

- They need to be interpretable by specialists in allied image interpretation.
- They should have a nice look because they should allow a quick overview on bomb penetration and waste pollution.
- They have to reveal small structures like small holes in the ground of blinders.
- The algorithm has to adapt to the failures of the available images.
- It has to keep the geometry of the image.
- It has to be as fast as the scanning of the image.

2.2 Scanning in detail and quality management of the scanned images

The aim of scanning is to optimize the information content, as well as the histogram, but not the optimization of the visual impression. Additionally, all radiometric properties of the analog images which are supposed to be scanned need to be reproduced in the digital images as good as possible. The complete reprographic range of each image is to be scanned during the scanning process.

In order to optimize the image information content, all digital images must fulfill the following general conditions: There must be no irregular swaths / scan lines and stains in the digital image, and the radiometric contrasts in the dark (shadows) and in the light image areas (clouds, snow, overexposed areas), which can be seen in the original image, must also exist in the scanned image.

Furthermore, the radiometric resolution of 16 bits must effectively be utilized. In addition the histogram of a so called inner range has to fulfill certain conditions. The inner range only contains objects which were captured during the original exposure. No superimposed fiducial marks nor any text are allowed to exist in the inner range.

The inner range has no constant offset to the unique label. In order to avoid complex individual detection of the inner range of each image, the inner range can be defined, so that the distance from the original image area on all four sides, does not exceed the value of 1,5cm.

Figure 1. Input Image

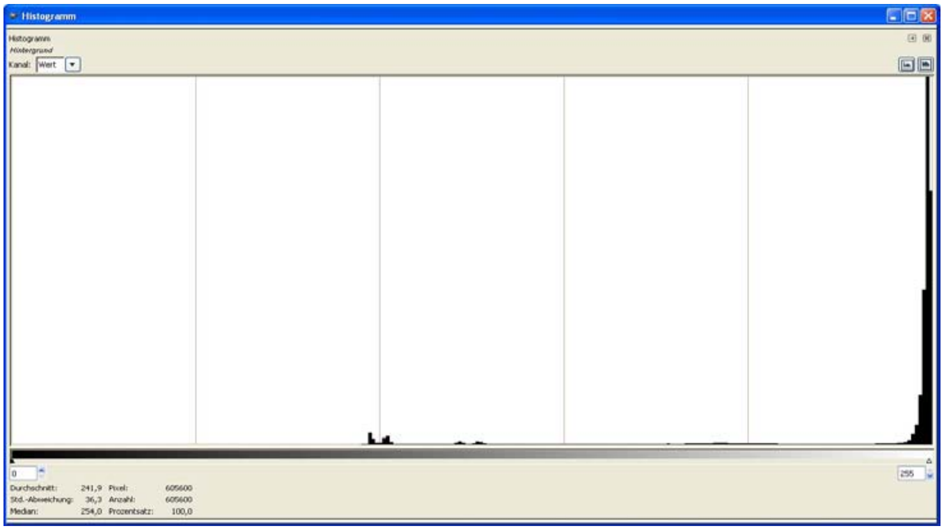
For the optimization of the image information the guideline of the scanning contains the following items:

- The histogram of the whole scanned image has to range from 6553 to 58983. Within this range the minimum of 245 grey values must possess a frequency greater than 0,01% of the number of pixels in the inner range,
- Maximally 0,01 % of all grey values in the inner range are allowed to exceed the grey value from 1 to 6553, and the grey value from 58983 to 65535.
- The grey values 0 and 65536 are not permitted.

Through the introduction of these boundary conditions, a later transformation to 8 bit is guaranteed, so that all objects of a 16 bit image taken during the photo flight are present. They can then be optimized during radiometric post-processing to avoid underexposures or overexposures in the 16 bit scanned image. The histogram derived from the 8 bit image is almost complete and the grey values from the 8 bit image are not derived from extrapolations.

3 Previous Work

Let I be the input image with $0 \leq I(x,y) \leq g_{max}$ for all pixels (x,y) of the image and H its histogram. Fig. 1 shows a scanned aerial image of an area in North Rhine-Westphalia and Fig. 2 its histogram.



Kanal: Wert

0

255

Durchschnitt: 241,9 Pixel: 605600
Std.-Abweichung: 36,3 Anzahl: 605600
Median: 254,0 Prozentsatz: 100,0

Figure 2. Histogram of input image after quantization to 8 bits.

The information of the input image is not recognizable for human eyes, since over 90% of all pixels have one of the 10%-highest grey values. The scanning of the image has been adjusted in such a way, that all information is preserved during the scan process. Thus, the frame of the image contains almost all the dark parts of the image. The rest of the image is too light for recognizing structures in the photographed landscape manually.

The analysis of the histogram of such an image shows that many grey values occur in the image, but most of them not more than only a few times. There is a number of small peaks in the middle of the histogram most of which result from the grey values of the image frame. The maximum in the histogram is located near the highest possible grey value g_{max}.

Finally, we denote the output image with *O(x,y)*.

3.1 Inner-range dodging with local histogram spreading

In a first approach, we use histogram spreading for improving the visibility in the images. Therefore, it is necessary to select an inner-range of an image to exclude the frame around the scene in the aerial image. The inner range has to be defined interactively due to writings on the

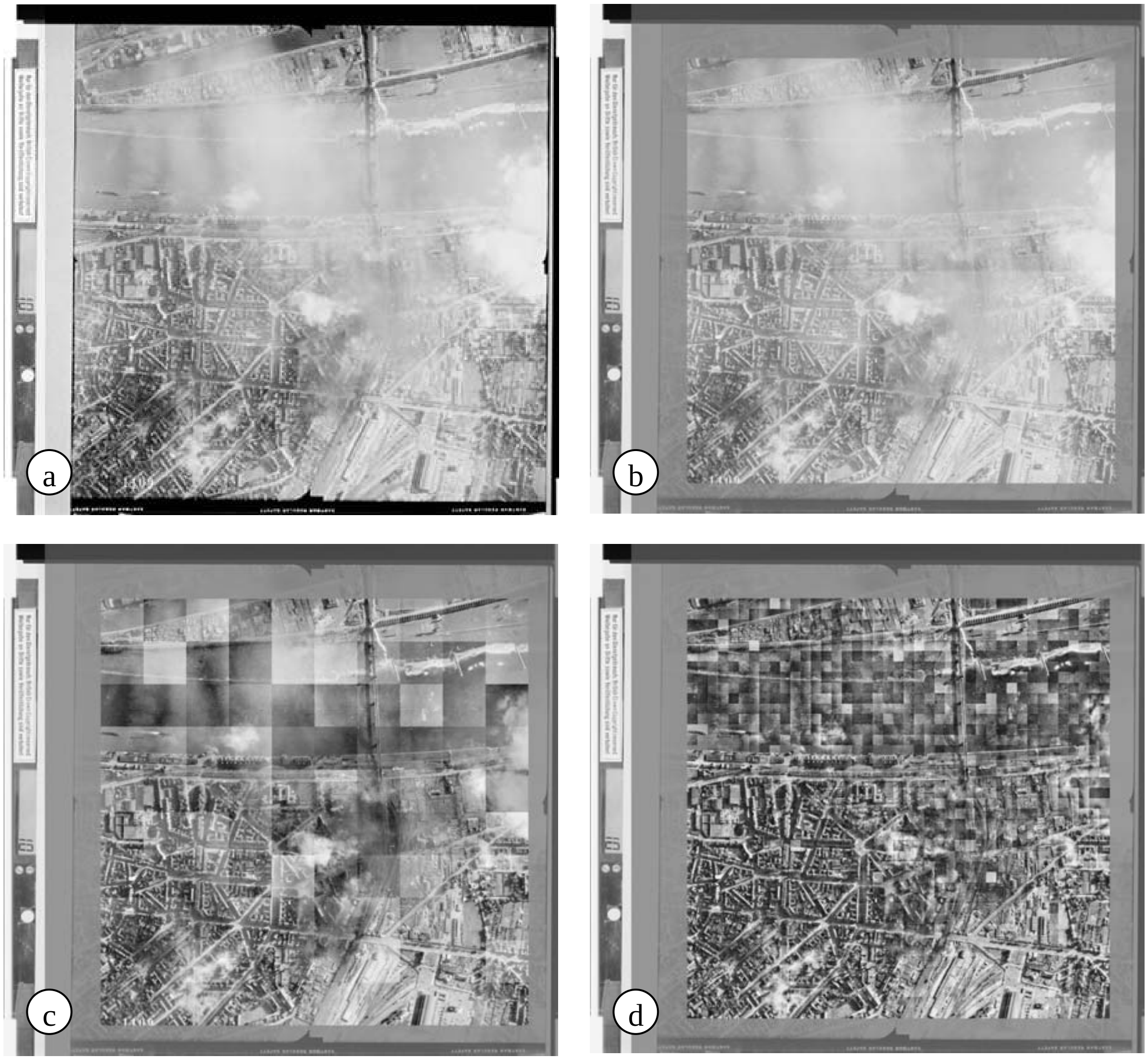


Figure 3. Dodging with histogram spreading. Part (a) shows the global approach, parts (b-d) show the results of an inner-range dodging with variable patch sizes. Therefore, we divided the image into 4 patches (b), 100 patches (c) or 400 patches (d) of equal size.

image and failures of image parts, also to exclude clouds, dust or reflection of sunlight. The inner range is divided into disjoint patches. For each patch, we determine the minimum and maximum gray values. Then we spread the histogram up to fixed anchor points, in which we define for 16 bit images with 65536 possible gray values 2560 as the minimum anchor point, and 62720 as the maximum. Disturbances in the image are not handled separately, thus many results show extreme discomposure. Fig. 3 shows the visibility improvements using the inner range dodging in four cases.

3.2 Multidodging with local mean-shift

Figure 4. Output image of multidodging approach.

The next approach manipulates the image using a transformation based on local parameters. Therefore, we call this method multi-dodging with mean-shift.

In a first step, we smooth the input image *$I_1(x,y)$* using Gauß-filters with a very large smoothing kernel, e.g. $\sigma = 51$. Then, we determine a difference image *$D(x,y)$* , which contains the absolute grey value differences between the original and the smoothed image, and we also determine a variance image $\sigma_D(x,y)$, where we store the squares of the difference.

In the second step of this method, we transform the grey values of the image by a linear transformation. The difference image *$D(x,y)$* is a good approximation of the local mean, thus we may transform the input image by the following linear function, where we adjust the image towards a constant mean and a constant variance:

$$O(x,y) = p_1 \frac{D(x,y)}{\sigma_D(x,y)} + p_2$$

We check all transformed pixel, if they are out of bounds, that means either $D'(x,y) < 0$ or $D'(x,y) > g_{max}$. The rate of all pixels which we have to correct afterwards, is low (around 3%), since we chose as parameters $p_1 = 20{,}000$ and $p_2 = 25{,}000$ for ingoing 16-bit-images.

The result of this approach is a strongly binarized image as shown in fig. 4. Its histogram consists of two peaks as demonstrated in fig 5.

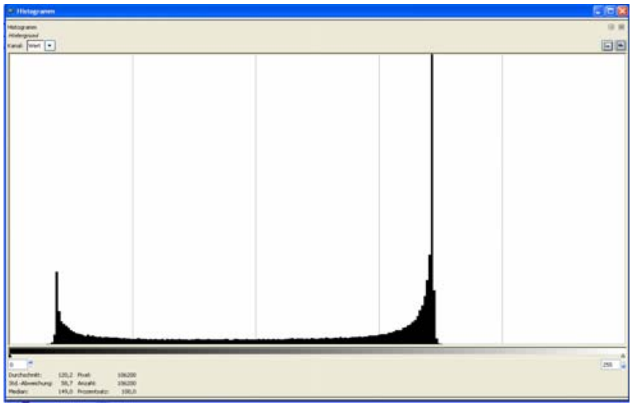


Figure 5. Histogram of output image of multidodging approach with mean-shift.

4 Results and Properties of the New Dodging Algorithm

Globally determined histogram equalizations return globally satisfying results. However the contrast in various image parts is still to low to distinguish small structures successfully. Consequently, we divide the image into p image patches P_i, with a fixed size for each patch and

$$I(x,y)=\bigcup_{i=1}^{p}P_i \quad \text{and} \quad P_i \cap P_j = \varnothing, \forall i \neq j \quad .$$

The borders between the image patches are clearly visible after transforming each image patch by its own histogram equalization E_i. Thus, the returned image cannot be just the union of the transformed image patches.

$$O(x,y) \neq \bigcup_{i=1}^{p} E_i(P_i(x,y))$$

Hence, we have to remove the edges between the patches without destroying significant edges within the image. Furthermore, we strengthen the contrast between equally colored objects and manipulate the contrast, where it is too strong.

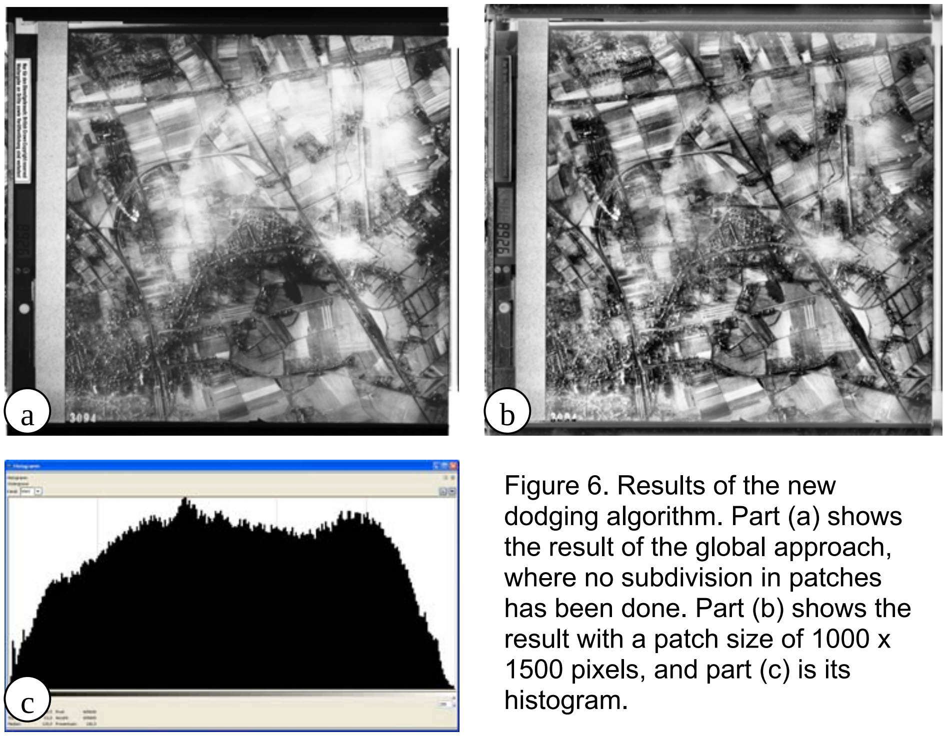


Figure 6. Results of the new dodging algorithm. Part (a) shows the result of the global approach, where no subdivision in patches has been done. Part (b) shows the result with a patch size of 1000 x 1500 pixels, and part (c) is its histogram.

We tested the algorithm on about 20,000 images. The performance of the algorithm is in the same range as the image scanning, it takes about 3-5 minutes. The radiometric resolution of the input and the output image may be chosen to be 8 or 16 bits.

We designed the program start in a way that each user may set the parameters for the patch size. Thus, we are able to demonstrate the performance of the dodging approach with different choices for the patch size. If it is chosen as big as the input image's size, the dodging is done globally. Alternatively, one may select patches which completely cover only a small number of image rows or columns, respectively. As seen in fig. 7, both tests lead to unsatisfying results since the contrast is quiet low in smaller image parts, e.g. around the bomb impacts. If the patch size is set too small, then some structures in the image are also only badly interpretable as demonstrated in fig. 7 when we show the result with 300 times 300 patches. In this case the noise is strenghened too much. The patch size for the best results takes the size of the histogram and the characteristics of the imaging process into account.

5 Summary and Outlook

In this article we have presented a project of the explosives disposal services of NRW for scanning and enhancing allied aerial images of the WWII. The resulting, dodged images have the quality that is necessary for image interpretation aimed at finding bombed areas and blinders. The tested software has the envisaged speed.

Meanwhile 20,000 images have been processed successfully. The production line of the dodging will be installed in short time. The digitization project will go on. Several tasks have to be realised for allied images during the next years, e.g. the automatic georeferencing of the scanned images, the automatic model building of flight stripes and the automatic interpretation of aerial images for bomb craters and blinders.

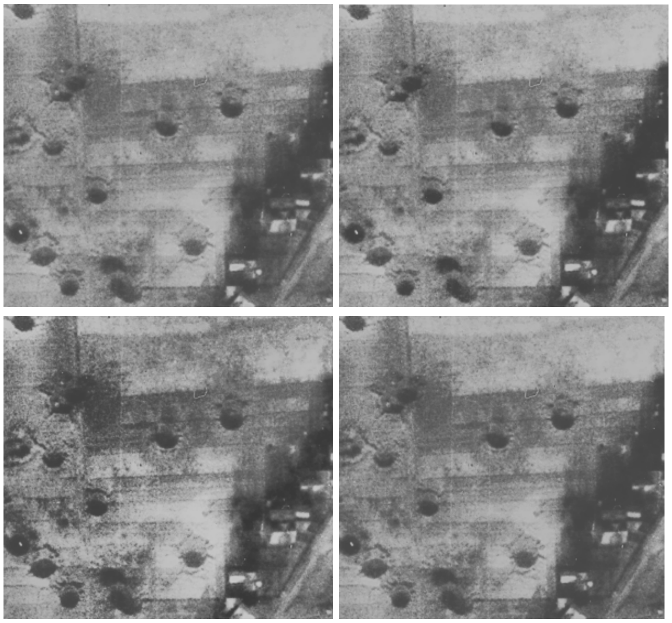


Figure 7. Effects of patch size for dodging results. First row left, only one patch has been used (global approach); right, row-wise dodging. Second row left, small patches with 300 x 300 pixels; right, bigger patches with 4000 x 4000 pixels.

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6 Literature

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