Indicators of Mine Presence: Focus on Trenches

Vinciane Lacroix [a,*], Sabine Vanhuysse [b]
[a] CISS Department, Royal Military Academy, Belgium
[b] IGEAT, Université Libre de Bruxelles, Belgium
*Corresponding author: Vinciane.lacroix@elec.rma.ac.be, +326426474

Abstract: As of October 2013, some 59 states and four other areas were confirmed to be mine-affected. Large ``Suspected Hazardous Areas'', often overestimated, prevent the population to use the land. In this context, aerial images provide an asset for a better delineation, based on indicators of mine presence (IMP) or of mine absence. Trenches detected thanks to their shadows are good examples of IMP. Their sparse presence over the huge amount of images makes their detection by a photo-interpreter an overwhelming task. We therefore propose an automatic tool based on dark line detection. In various envisaged scenarios, the most suspicious images and the detected objects are proposed to photo-interpreters for further analysis or for pre-processing such as ortho-photo production. The tool is applied to the Suspected Hazardous Area of Bihac in Bosnia and Herzegovina.

Keywords: Feature extraction, Humanitarian Demining, Image Processing & Analysis, Linear object extraction, Remote Sensing,

Introduction

The presence of anti-personnel mines is currently a problem in some 59 states and four other areas (Landmine Monitor, 2013). Large ``Suspected Hazardous Areas'' (SHAs) prevent the population from circulating and using the land. SHAs are often overestimated. In Mine Action, the “Non-Technical Survey” (NTS) described in the International Mine Action Standards (IMAS4.10, 2003), is a process aiming to reduce SHA into “Confirmed Hazardous Areas”, thus releasing land where there is no evidence of mine contamination.

Aerial photographs have been considered in Humanitarian Demining since 1998 (Van Genderen et al, 1998) for the purpose of individual mine recognition but with little success. Maathuis then introduced the concept of indirect minefield indicators (Maathuis, 2003). It is only after the SMART project (Yvinec, 2004) that a method could be considered as a basis for AIDSS, an operational tool designed to find indicators of mine presence (IMP) and indicators of mine absence (IMA). The tool is currently used in Croatia (Bajic et al, 2011).

In the scope of the EU FP7 TIRAMISU (Toolbox Implementation for Removal of Anti-personnel Mines, Submunitions and UXO) project, methods to detect and map IMAs and IMPs on aerial and satellite images are being developed and tested. The choice of indicators results from an analysis involving photo-interpreters and possibly former members of the military who took part in the conflict that caused the contamination. In the case of military conflicts, trenches are examples of IMPs. The first step for detecting an IMP/IMA consists in translating the indicator in terms of basic image features. As trenches can be detected thanks to their long straight

linear shadows, the automatic tool we propose is based on dark line detection. The low occurrence of trenches in the huge amount of aerial photos collected during a flight over a SHA makes the task overwhelming. Various scenarios using this dark line detector are proposed to extract some suspicious photographs from the whole set.
The paper is organized as follows. Section 2 describes the line extraction process and the properties used for useful line discrimination. Section 3 explains how this process is used for detecting trenches. The results on the Bihac region of Bosnia and Herzegovina are provided in Section 4. Conclusions are presented in Section 5.

Line extraction

The success of line detection relies on (i) a line filter producing at each pixel the contrast of the line and its direction, (ii) an efficient non-maximum suppression to extract the line axis, (iii) an appropriate linking of line elements, and (iv) a set of relevant local properties.

2.1. Line Filter

The filter is based on the Gradient Line Detector (GLD) exploiting the change in gradient direction at each side of a line (Lacroix et al, 1998). More precisely, consider the 8-neighborhood of a given pixel p, and arrange the neighbours in pairs (a_k, b_k) as in Figure 1 (a). Let $\mathbf{G}(a_k)$ denote the gradient of the intensity at pixel a_k, then:

Step1: for each of the four pairs of the 8-neighborhood of pixel p:

(a) Compute $\mathbf{L}(p)=\mathbf{G}(a_k)-\mathbf{G}(b_k)$; if a line is present at p, $\mathbf{L}$ is perpendicular to the line.

(b) If $\mathbf{L}(p)\neq 0$ and if the pair (a_k, b_k) is not along the direction of $\mathbf{L}$, compute

$P_k=\mathbf{G}(a_k) \blacksquare \mathbf{G}(b_k)$, where ■ denotes the dot product.

If $P_k < 0$ keep the pair (a_k, b_k) for which is $|P_k|$ is maximum.

Step 2: if for all pairs $P_k \geq 0$, $\mathbf{GLD}(p)= 0$ (there is no line at p)

else let (a_k, b_k) be "the best pair", i.e. for which $|P_k|$ is maximum, then compute:

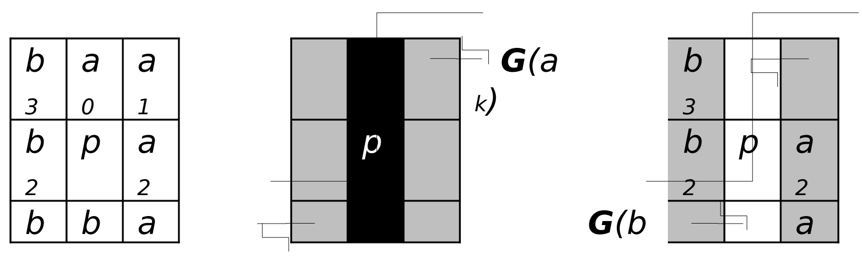
$Pa_k=\mathbf{G}(a_k) \blacksquare \mathbf{1}a_k$, the projection of $\mathbf{G}(a_k)$ along a_k ($\mathbf{1}a_k$ is the unit vector in the direction of a_k)

$Pb_k=\mathbf{G}(b_k) \blacksquare \mathbf{1}b_k$, the projection of $\mathbf{G}(b_k)$ along b_k ($\mathbf{1}b_k$ is the unit vector in the direction of b_k.)

If Pa_k and Pb_k have the same sign $\mathbf{GLD}(p)= -\sqrt{|P_k|}$ if $Pa_{k>0}$ (dark line: see Figure 1 (b))

$\mathbf{GLD}(p)= \sqrt{|P_k|}$ if $Pa_{k<0}$ (bright line: see Figure 1 (c))

otherwise $\mathbf{GLD}(p)= 0$. The line direction is provided by $\mathbf{L}(p)$ (see Step 1 with the best pair).



(a) (b)

(c)

Figure 1 (a) Local neighborhood at *p*; (b) dark line at *p* ; (c) bright line at *p*.

Step3: step 2 may produce some parasite lines due to quantization effects; this happens if the gradient norm at a_k (b_k), is much larger than the norm at b_k (a_k). The following constraint (we use α = 0.2) enables to remove these parasite lines:

If $\boldsymbol{GLD}(p) \neq 0$ and $||\boldsymbol{G}(a_k)|| > ||\boldsymbol{G}(b_k)||$ and $||\boldsymbol{G}(b_k)|| < \alpha ||\boldsymbol{G}(a_k)||$ or $||\boldsymbol{G}(b_k)|| > ||\boldsymbol{G}(a_k)||$ and $||\boldsymbol{G}(a_k)|| < \alpha ||\boldsymbol{G}(b_k)||$ then $\boldsymbol{GLD}(p) = 0$.

Step 1 (b) and Step 3 are enhancements brought to the GLD.

By definition GLD is negative for dark lines. A signed GLD offers a more efficient storage than two GLDs (for bright **and** for dark lines) as occurrence of both types of lines at the same location is rare. For lines of similar width, the absolute value of the GLD is proportional to the contrast of the line; the direction perpendicular to the line is provided by $\boldsymbol{L}(p)$.

2.2. Non-maximum suppression

This process provide line axes; it is similar to non-maximum suppression used for edge detection; for bright (dark) line extraction, the GLD of a pixel which is not maximum (minimum) in the direction perpendicular to the line is set to zero. If two by two pixels patches remain at this stage, the pixel whose deletion does not modify the local topology is set to zero. Let *MaxL* be the matrix resulting from this non-maximum suppression.

2.3. Computing local line width and contrast

Local Line width is computed by associating the middle of the line (i.e. axis) with its borders. One pixel large edges are thus generated using non-maximum suppression on $||\boldsymbol{G}(p)||$, providing the matrix *MaxE*. Then, for each pixel *p* not part of a line axis (i.e $MaxL(p) = 0$), a vector $\boldsymbol{v}$ associating *p* width the “best” edge element (edgel) is computed. The process starts with the largest gradient norms. If *p* is an edgel (i.e $MaxE(p) > t$, where *t* characterizes the minimum contrast of a “true” edgel), then $\boldsymbol{v} = 0$. Otherwise the two pixels in the 8-neighborhood lying on the line along $\boldsymbol{G}(p)$ are sought; $\boldsymbol{w}$, the displacement to pixel *q* with the maximum norm is stored. If *q* is an edgel (i.e $MaxE(p) > t$) then $\boldsymbol{v} = \boldsymbol{w}$, else $\boldsymbol{v} = \boldsymbol{w} + \boldsymbol{v}(q)$. Then, for each pixel *p* lying on a line axis (i.e $MaxL(p) > t$), the pixels at each side of the axis in direction $\boldsymbol{L}(p)$) are considered, their respective vector $\boldsymbol{v}$ linking them to the best edgel enables to associate *p* with two edgels; the local width is the distance between the two edgels. Once a line element is associated with two edgels, the contrast of the line is taken as the average of the gradient of both edgels; it provides a better estimation of the contrast than the GLD in the case of large lines.

2.4. Linking line elements and computing line attributes

Line elements are linked, generating line segments on which the average of the contrast, width and orientation are computed. At this stage holes between segments are not filled. The result of this process is a list of vectors describing each line segment axis together with contrast, width, angle and length attributes.

3. Trenches detection

Red, Green, Blue and possibly panchromatic channels may be available for trench detection. As linear shadows should be detected, the channel offering the highest dark line contrast is kept for Line extraction. The IMP (i.e. trenches) should then be translated into image features according to image resolution and scene characteristics. In this case the minimum length (in pixels) of the line segments and the minimum average width (in pixels) should be provided. More technical parameters such as *t*, the minimum contrast of a line and the smoothing factor of the Gaussian Gradient are set by default to 5 and 1 respectively. Several scenarios were envisaged, all of them analysing the series of images taken during the campaign. In the first one, information about potential trenches orientation is provided thanks to old annotated scanned maps, focusing the detection on a specific orientation. In another one, the detection in a specific orientation will be avoided; this could be an option in areas where tree shadows may generate a lot of dark lines. In the most general scenario, no constraint on the orientation is provided. In all cases, line features satisfying the constraints are provided as a list vectors ranked based on the average line contrast. The vectors may be superposed on the image or imported in a GIS. The most suspicious image is the one providing the bigger total length of valid segments.

When looking at the results, the photo-interpreter may consider the image as suspicious and note it for further visual analysis, OBIA analysis (Vanhuysse et al, 2014) or processing such as ortho-photo production. Depending on the detected features, the user may wish to restart the process with different parameter setting. Such scenario has been considered for the data set made of the aerial campaign performed over Bosnia Herzegovina.

4. The case study of Bihac (Bosnia and Herzegovina)

An aerial campaign over the Suspected Hazardous Areas of Bihac has been performed in 2010. Five stripes of 17 color photographs of size 4288x2848 were taken using Nikon D90 camera. The resolution is about 10 cm. As the area is covered by forest, the photographs contains a lot of tree shadows (see Figure 2 Left). The result of launching the dark line detector with minimum length of 180 pixels and a minimum width of 5 pixels provides only three suspected photographs all of which contain trenches. Part of the most suspected one is displayed in Figure 2 (right), together with the superimposed detected linear objects.

Figure 2. Parts of two color photographs of stripe 1. Left: non suspicious photograph. Right: Most suspicious photograph with linear objects superimposed in blue (min length= 180, min width= 5) .

5. Conclusions

An automatic line detection algorithm was enhanced and incorporated in a process aiming at providing to photo-interpreters involved is SHAs analysis some assistance to rapidly identify elements of trenches in series of images resulting from an aerial campaign, allowing to speed up the pre-processing and the analysis of the scene. The process was successfully tested over a campaign performed in Bosnia and Herzegovina.

6. Acknowledgements

HCR Centre for testing, development and training Ltd. provided airborne images collected with the project Deployment of the Decision Support System for Mine Suspected Area Reduction in Bosnia and Herzegovina, supported by financial aid of the US State Department, through the International Trust Fund for Demining and Mine Victims Assistance (ITF).

The research is funded by the EC FP7 Security TIRAMISU Project GA 284747.

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