Differential Morphological Profile for Threat Detection on Pipeline Right-of-Way

Heavy Equipment Detection

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***Abstract* - Unsupervised construction on the pipeline may provoke pipe rupture and consequently gas leaks. Monitoring the pipeline right-of-way for heavy equipment is important for environmental and human safety. Remotely sensed images are an alternative to expensive and time consuming foot patrol. Existing image processing methods make use of previous images and/or external data. Both are not always awailable. We propose a new method for image processing to detect heavy equipment without the need of auxiliairy data.**

Keywords-remote sensing image processing; right-of-way threats detection; histograms of oriented gradients; differential morphological profile.

I. INTRODUCTION

The periodic surveillance of gas and oil pipeline's Right-of Way (ROW) is vital to protect the human safety and to prevent ecological damage. Though most of the incidents are related to gas leaks, excavation activities are considered responsible for as much as two third of the incidents for the period 2002-2008 [1]. Recognizing dangerous activity, such as digging or construction equipment (threats), near the pipeline and undertaking prompt measures to insure safety is an obligation of oil and gas companies. Pipeline networks span thousands of kilometers and may be located in remote areas. Walking the ROW to survey for heavy equipment and dangerous activity is highly costly and time consuming. The alternative is the use of remotely sensed imagery.

So far the most reliable interpretation of these images remains the one made by human. The automation of the process faces difficulties from different origin: great variety of vehicles; uneven flight altitude; different view and orientation of the images; variable illumination conditions; occlusion by neighboring objects, and others [2]. In addition, construction vehicles are sometimes very similar to transportation vehicles. All these make the development of pattern recognition algorithms for ROW threat detection a challenging remote sensing image processing task.

Existing methods extract characteristic features to decrease the differences between construction vehicles (decrease the inter-class heterogeneity), while increasing the intra-class heterogeneity, i.e. make heavy equipment more distinguishable from other objects. In [3], scale-invariant feature transform was applied on previously defined scale invariant regions to receive object descriptors and detect vehicles. Presuming that local distribution of oriented gradients (edge orientations) is a good indicator for the presence of an object, Dalal [4] proposed the accumulative Histogram of the Oriented Gradients (HOG). In [5], the authors mapped HOG to Fourier domain to achieve rotation invariance and used kernel Support Vector Machine (SVM) to classify the data and identify construction vehicles. Using local textural descriptors and adaptive perception based segmentation, the authors in [2] sequentially eliminate background objects from the image, such as buildings, vegetation, roads, etc. The remaining potential threat locations are divided into several parts to extract and evaluate descriptive features and match them against template data. Extraction of local phase information allowed the separation between structure details and local energy (contrast) [6]. Afterward based on a single image template, the authors created a voting matrix to detect construction vehicles. To avoid the need of image template, potential threats locations are assessed with the aid of change detection in [7], next auxiliary data is used to decide upon the presence of a threat. Synthetic aperture radar images provide all weather coverage and together with optical images are used to produce a time sequenced image analysis for change detection and threat localization [8]. Existing methods need image templates or previous images and auxiliary data. Such external data is not always available.

We present a new methodology that avoids both, the need of image template and the need of auxiliary data. In addition to increased flexibility, it also makes the performance of the method nondependent on the quality of the external data. The rest of the paper is organized as follows. In section II we describe the method. Section III presents some results and validation, and conclusion is given in section IV.

II. DESCRIPTION OF THE METHOD

To build our method we take advantage of the fact that construction vehicles have non-flatten surfaces, which creates inequality in the intensity of surface pixels and together with their outer edges make that they appear as areas of high frequency in the image. Therefore, potential threat locations may be found by identifying areas of high frequencies that are in the range of heavy equipment size. Further, different descriptors may be used to discriminate between heavy duty vehicles and other objects. This is the general workflow of our method. To account for different illumination conditions we compute the color invariant of the blue band. To highlight frequencies (edges) we compute the gradient of the color invariant and retain only high frequencies applying a threshold on the gradient. The gradient is computed using the Otsu's method. To identify only areas in a certain size range we apply the Differential Morphological Profile (DMP). DMP is an iterative algorithm that performs opening/closing by reconstruction with a structuring element (SE). The size of the SE is increased in the consecutive iteration and the result is extracted from the result of the previous iteration. When the SE size exceeds the object size, the background intensity values are assigned to the object. Thus, by extracting two consecutive results, only objects that correspond to the SE size are retained. We derived the size of the SEs from the

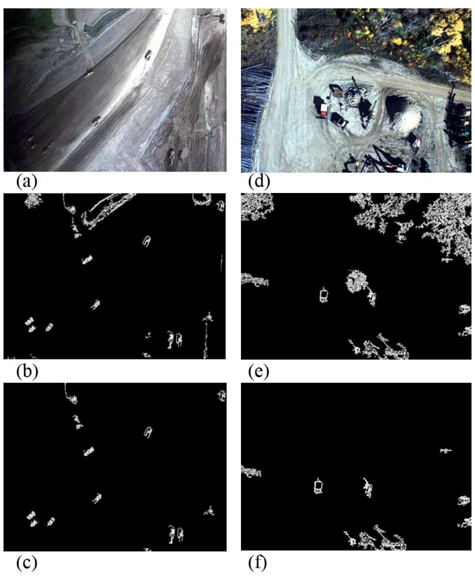

Figure 1. ROW threats detection. (a) and (d) - Original images; (b) and (e) - Results of the application of DMP: SE = 8x8 pixels; (c) and (d) - Detection.

size of the target object and the pixel size of the image. For each received object we compute the following descriptors: HOGs, curvature, the ratio between the major and minor axis of the object. Using all the descriptors simultaneously rather than thresholding each one separately, allows better assessment of the similarity between objects. To find the most similar objects we retain objects that maximize the ratio between the first and the last eigenvalue of the vectors. Finally, we apply spectral and shape constraint to discriminate between construction equipment and cars.

III. RESULTS AND VALIDATION

We present some results in Fig. 1. The first column (a) represents the original image, the second column (b) - the result of DMP, and the third column (c) - the detection.

To validate the accuracy of the method we compared the results to the results of manually detected threats. We refer to the latter as ground truth data. A test from 3 flight days (more than 1000 images of 1200x800 pixels with average pixel resolution of 9 cm) reveals a detection rate of 82.6% - heavy equipment machines that are present in the ground truth data and were detected by the algorithm. At this stage of the development of the algorithm we are less concerned with the rate of false recognition, as the results are reviewed by an operator. We consider including additional descriptors to reduce the number of false positives events while increasing the detection rate.

An advantage of using DMP is that by changing the shape of the SE different shape may be detected, changing the size of the SE allows the detection of construction machines with different size and also to account for the changing height of the flight. As the height of the flight in our case does not change a lot we derived the size of the SE empirically. If this height changes a lot, an automate way to choose the size of the SEs in accordance with the flight parameters should be adopted. In our opinion the method may have limited performance when applied on images with much lower spatial resolution, more than 1 meter for example, as it relies explicitly on information taken from an increasing neighborhood.

IV. CONCLUSION

We presented a new methodology for the detection of threats on the pipeline ROW that does not involve the use of external data. The initial results are promising and we believe that the method has the potential to replace the manual processing of the images.

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