

WAVELET DIFFERENCE REDUCTION WITH REGION-OF-INTEREST PRIORITY IN MULTISPECTRAL VIDEO - SMALL TARGET DETECTION

Yee Louise Law[†], Frank Crosby^{*}, Quyen Huynh^{*}, Truong Nguyen[†]
University of California, San Diego[†]

Naval Surface Warfare Center, Dahlgren Division, Panama City, Florida^{*}

ABSTRACT

A preliminary detection algorithm and wavelet difference reduction (WDR) with region of interest priority compression are combined to successfully identify small targets in multispectral imagery. The technique addresses not only detection capability, but also practical unmanned aerial vehicle (UAV) implementation restrictions. The restrictions that are overcome are small processing capability and variable bandwidth datalinks.

1. INTRODUCTION

The surveillance imagery acquired by unmanned aerial vehicles (UAVs) must be transmitted in order to provide critical real-time reconnaissance information. The datalinks of UAVs have a very limited capacity. The capacity can vary and may go as low as 10 Mbps. Furthermore, on board processing is restricted by payload and power restrictions. The only way to receive any useful data is to compress it and the algorithm must not require intensive computations. Common commercial and personal users of digital imagery are most concerned with the dominant objects in the images.

Most compression and processing algorithms were designed with that in mind, so they first sacrifice fine image detail. However, target detection in surveillance imagery depends on finding objects that may only be a few pixels in size. It is the large structures that have a smaller importance. This means that the application of traditional compression algorithms, such as JPEG [1, 2], will remove the targets from the imagery, making it impossible to recover the vital information and perform target detection. Research has been focusing on the design of compression and processing algorithms for smaller objects using the region of interest (ROI) principle.

We applied Wavelet Difference Reduction (WDR) compression [3] with ROI priority to landmine detection in multispectral video. WDR compression algorithm is employed because of the following reasons:

1. Extremely fast implementation using Daub 5/3 Int-to-Int wavelet transform [4, 5, 6]
2. Low power requirements
3. High fidelity
4. Scalability
5. Region-of-Interest priority

In this study, the block-based WDR and region-of-interest (ROI) compression at different compression ratios are evaluated. The result shows that the compression algorithm well preserve the minefield images and does not interfere with a standard detection algorithm.

2. OVERVIEW

This multispectral imagery was collected by cameras that capture a cycle of spectral bands with each spectral band in a separate video frame. A system using this type of camera has been used for airborne mine detection [7].

The imagery is processed for compression on a per frame basis. Preliminary detection identifies ROIs. A significant percentage, 95%, of the available bits is evenly distributed among these regions. Since base-stations can provide more computing power, decompression and registration processes will likely take place at a ground station after the bitstreams are received. Then multispectral detection and pattern recognition algorithms are run on the processed images to assess accurate target locations. The process flow is shown in Figure 1.

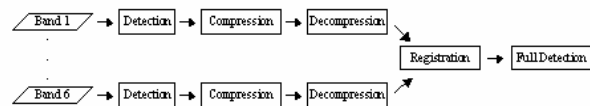


Figure 1: Imagery processing flow

In order to assess the effects of compression, 20 sets of multispectral images were processed. We began with registered images to isolate the effects of the compression in three ways:

1. Detection without compression
2. Detection & WDR compression
3. Detection & WDR-ROI compression

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In this study, the feature of multiple ROI compression is appended to the current WDR compression algorithm. The number of ROI depends on the number of points that are generated from the detection algorithm.

3. COMPRESSION METHOD

Research has been focusing on the design of compression and processing algorithms for smaller objects by using ROI priority. When low-bit rates and high compression ratios are required, or when the features such as mines needed to be preserved, the ROI feature allows the operator to interactively select several regions of interest requiring higher perceptual visual quality. At the encoder in field, the algorithm allocates more bits to the ROIs and fewer bits to the background. Allowing for multiple regions means that selecting one target does not sacrifice the accuracy of another target. As bandwidth increases, the perceptual quality of the whole image improves. In minefield mapping operations, this feature could be used to span the field quickly and then zoom in on an area where a potential threat or a suspicious object was found.

The proposed compression algorithm is based on integer wavelet transform where fast structure and low power realization are implemented, which enables real-time system. The encoding technique is based on the Wavelet Difference Reduction (WDR) algorithm where the encoded bit stream is coded based on the significant coefficients of the bit-plane (from Most-significant-bit to Least-significant-bit) [8]. The WDR algorithm consists of four parts, as shown in Figure 2. In the Initialize part, an initial threshold value, T , is chosen so that all transform values have magnitudes that are less than T , and at least one has magnitude greater than or equal to $T/2$. The purpose of the loop indicated in Figure 2 is to encode significant transform values by the method of *bit-plane encoding*. A binary expansion, relative to the quantity T , is computed for each transform value. The loop constitutes the procedure by which these binary expansions are calculated. As the threshold is successively reduced by half, the Significance Pass and Refinement Pass compute the next bit in the binary expansions of the transform values. See [3, 7] for a more complete description of bit-plane encoding.

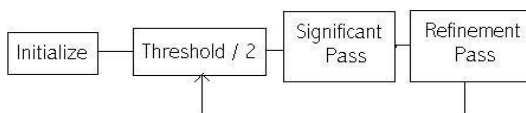


Figure 2: Wavelet Difference Reduction Algorithm

To realize the maximum benefits of WDR (fast implementation and low power requirement), a 4-levels Daub 5/3 Int-to-Int transform is used. The WDR

compression algorithm provides both global and block-based compression methods. From the performance comparison of the two methods, block-based compression outperforms the global one significantly. Hence, block-based compression algorithm is employed in this study. By using the block-based method, we gain an additional advantage of lower internal memory requirement.

4. DETECTION METHOD

The FX target detection algorithm is an adaptive constant false alarm rate technique that uses spatial and spectral information [9]. The FX algorithm is an adaptive algorithm that owes its success to the few assumptions placed on the data. A limited number of assumptions allow it to be applicable in many different situations. The FX algorithm is a scalar-valued function of the possibly multi-dimensional quantities: average target intensity, the average background intensity, and the common covariance of the background and target. In the preliminary detection stage, which takes place before compression, these quantities are one-dimensional. After decompression, the FX algorithm is used again in its multi-dimensional form for multispectral detection.

A local sample of the image of size is divided into three disjoint sets, background pixels, possible target pixels, and guard band pixels that likely contain both target and background contributions. The guard band pixels are not used in the detection metric calculation.

The mean of the target pixels are given by $\sum_{N_T} \mathbf{t} / N_T = \mu_T$, where N_T is the number of target pixels. The mean of the background is given by $\sum_{N_B} \mathbf{b} / N_B = \mu_B$, where N_B is the number of background pixels. The means of the background and target can be used to compute the common covariance matrix: \mathbf{S} . The detection metric is calculated as

$$F(\mathbf{X}) = \frac{N_B N_T}{N_B + N_T} (\mu_B - \mu_T)^T \mathbf{S}^{-1} (\mu_B - \mu_T).$$

5. EXPERIMENTAL RESULTS

Several compression ratios (8:1, 16:1, 32:1, 64:1, 128:1) are evaluated on two types of images, beach and grass. Due to the fact that the grass images have very similar statistics between mines and backgrounds, a high compression ratio distorts the image and degrades the detection performance. Therefore, only 8:1 and 16:1 compression ratios yielded good results for the grass images. On the other hand, mines are more prominent in the beach images thus; higher compression ratios (32:1 and 64:1) can be used without removing the important

information. The size of ROI is set to be the same size as the target mask.

The main purpose of this study is to confirm that the selected compression algorithm will not degenerate the operation of current detection algorithm. Therefore, the number of points of detection might not cover all mine locations and only an optimal number is being applied. Initially, the detection process produces a list of 15 and 150 point-of-detection from the beach and grass images respectively. The detection rate for all three cases is around 80%. A second attempt of doubling the number of detection points is generated. The result shows that the beach images yield a significant increase in detection rate; however, there is only a minor improvement for the grass images. Consequently, the following experiment conducts with a list of 30 and 150 point-of-detection for the beach and grass images respectively.

Figure 3 shows one band of an image of a beach area and Figure 4 shows the strongest multispectral detection results. The squares in the detection images indicate correctly identified targets (not all false alarm detections are shown in the figures).

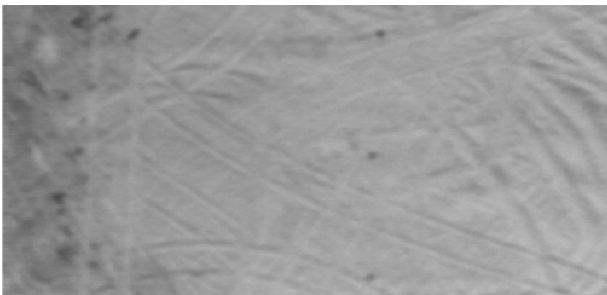


Figure 3: Band number three of a six-band set of a beach scene



Figure 4: Detection on uncompressed six-band set of the beach scene in Figure 3.

In Table 1, we summarize the number of correctly detected mines under three different situations and two different compression ratios (32:1, 64:1) on the beach images. The following statistics shows that both block-based and ROI compression at 32:1 ratio outperforms the detection only situation. This was largely due to the nature of the targets in the multispectral imagery. The true

targets tended to have a significant contrast against the background in most of the bands. Background variations that create false alarms are usually only present in a few bands. Consequently, the combined resolution of true targets, as measured across all bands, is much greater than that of false alarms. This means that an anomaly that might create a false alarm in uncompressed imagery is less prominent after compression.

Image	Detection only	BB 32	BB 64	ROI 32	ROI 64	# of mines per image
B-1	5	5	5	5	4	5
B-2	5	5	5	5	4	6
B-3	7	7	5	7	5	7
B-4	5	6	5	6	6	8
B-5	8	8	7	8	6	8
B-6	5	5	5	5	5	5
B-7	4	4	4	4	4	6
B-8	5	5	4	5	4	5
B-9	5	5	5	5	5	5
B-10	4	4	4	4	4	5
Total # of detections	53	54	49	54	46	60
Total # of miss	7	6	11	6	14	
Detection Rate	88.33%	90%	81.67%	90%	76.67%	

Table 1: Number of mines detected and statistics of beach images (BB: block-based; ROI: region-of-interest block-based)

Figure 5 shows band number six of a grass scene. Figure 6 shows the strongest detection in the scene with the true target detections surrounded by a box. The grass imagery produces many more false alarms than the beach scenes.

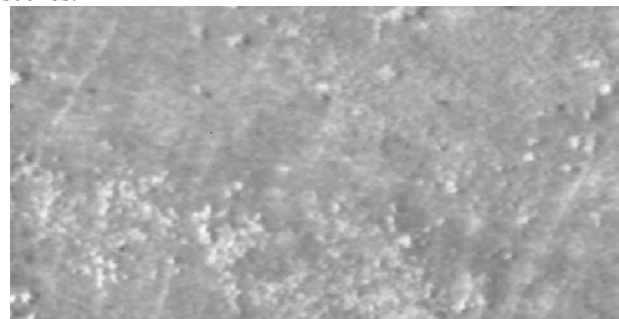


Figure 5: Band number six of a six-band set of grass images

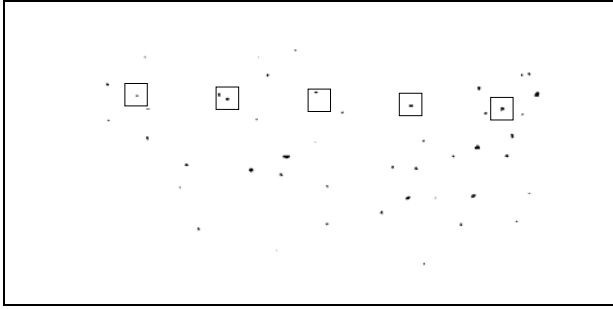


Figure 6: Detection on original grass image

Table 2 shows the number of correctly detected mines of grass images. All the compressed images give a higher detection rate than detection only condition. Furthermore, the ROI method produces better results than compression without using ROIs.

Image	Detection only	BB 8	BB 16	ROI 8	ROI 16	# of mines per image
G-1	9	8	8	9	8	12
G-2	5	5	5	5	5	5
G-3	8	7	7	7	8	10
G-4	9	10	10	10	10	10
G-5	4	4	4	5	5	5
G-6	6	7	7	7	7	10
G-7	4	5	5	5	5	8
G-8	5	5	5	5	5	5
G-9	9	9	9	9	9	10
G-10	4	4	4	4	5	5
Total # of detections	63	64	64	66	67	80
Total # of miss	17	16	16	14	13	
Detection Rate	78.75%	80.00%	80.00%	82.50%	83.75%	

Table 2: Number of correct mines detection and statistic of grass images

6. CONCLUSION

Limited bandwidth for UAV based surveillance makes compression necessary. Small target detection in this surveillance imagery requires novel compression techniques. The techniques that have been presented offer solutions to these constraints. WDR provides extremely fast implementation using Daub 5/3 Int-to-Int wavelet transform, low power requirements, and region-of-interest priority.

In addition to satisfying UAV derived constraints, the compression technique that was tested also suppressed false alarms in multispectral imagery. It gave better detection rates than the uncompressed imagery. The improved detection rates are dependent on target signatures that are prominent in most of the multispectral bands and may not be duplicated with other targets. However, any successful multispectral based target detection system will rely on targets that are at least as prominent as natural background variations. Therefore, at least equal detection rates between compressed and uncompressed imagery is expected.

7. REFERENCES

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