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Ship Detection from SAR Imagery Using CUDA and Performance Analysis of the System

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ABSTRACT
Synthetic aperture radar (SAR) Ship Detection System SDS is an important application from the point of view of Maritime Security monitoring. It allows monitoring traffic, fisheries, naval warfare. Since full-resolution SAR images are heavily affected by the presence of speckle, ship detection algorithms generally employ speckle reduced SAR images at the expense of a degradation of the spatial resolution. The proposed Parzen-window-kernel-based algorithm and CFAR algorithm can be considered an alternative to manual inspection for large ocean areas. Promising results and high detection rates for the ships have been achieved. In Parzen-window-kernel-based algorithm for ship detection in synthetic aperture radar (SAR) images, first, the data-driving kernel functions of Parzen window are utilized to approximate the histogram of real SAR image, in order to complete the accurate modeling of SAR images. Then ship detection is implemented using a Constant False Alarm Rate (CFAR). After detecting threshold, the output is added to edge detection algorithm employed on SAR image. Clearer detection of ship candidates is obtained by applying Parzen-window-kernel-based algorithm by changing its window size. Experimental results show that SDS implemented using CUDA is faster than on CPU.
Keywords - SAR, Parzen Window, CFAR, Ship detection

I. INTRODUCTION

Knowing the position and identity of all ships in a region is crucial to many industrial, leisure and governmental activities and the accuracy and completeness of this information can have far-reaching consequences [1]. Transportation companies optimize the routes used by their fleets to save costs. Port authorities manage marine traffic to ensure safety. National security and enforcement agencies supervise entire coastlines for security threats and illegal activities [3]. Fishing management organizations develop quotas and monitor restricted fishing areas. Environmental monitoring groups detect the source of marine pollution. A complete marine situational awareness allows militaries to manage resources and develop effective strategies. Market traders track marine traffic to forecast commodity prices. Many methods for detecting ships have been in use and steadily improving for decades. Earth observation satellites can scan large expanses of marine areas in a short amount of time. Unfortunately, there are less ship detection methods that detect ships from SAR images quickly. Most of existing Ship Detection System runs sequential code, if SDS runs CUDA code then ship candidates can be detected within some couple of seconds.

II. SYNTHETIC APERTURE RADAR

Synthetic-aperture radar (SAR) is a form of radar which works on the principle of relative motion between an antenna and its target region, to provide distinctive long-term coherent-signal variations [4]. These signal variations are exploited to obtain finer spatial resolution than is possible with conventional beam-scanning means. SAR is mounted on a moving platform such as an aircraft or spacecraft, a single beam-forming antenna from which a target scene is repeatedly illuminated with pulses of radio waves at wavelengths anywhere from a meter down to millimeters. Many echo waveforms received successively at the different antenna positions are coherently detected and stored and then post-processed together to resolve elements in an image of the target region.

FORMOSAT-1, FORMODAT-2 provides resolutions up to 2m, resolutions provided by ultra-wideband systems is a few millimeters, and experimental terahertz SAR has provided resolutions up to sub-millimeter. SAR images have wide applications in remote sensing and also in geoscience. SDS uses SAR image taken by FORMOSAT-2, which is high resolution image with size of around 500MB to 1GB. Images in remote sensing and geoscience are of TIFF file format.

III. COMPUTE UNIFIED DEVICE ARCHITECTURE

Compute Unified Device Architecture is a parallel computing platform and programming model created by NVIDIA and implemented by the graphics processing units (GPUs). CUDA is proprietary of Nvidia, so CUDA programs can only be run on

Nvidia GPUs [4]. This programming model allows developers to access virtual instruction set and memory of the parallel computational elements in CUDA GPUs. Using CUDA, the latest Nvidia GPUs become accessible for computation like CPUs. CPUs have less number of cores, so any sequential program runs on limited cores. However, in GPU there are thousands of cores and thousands of threads. This approach of solving general-purpose problems on GPUs is known as GPGPU.

1. Advantages of CUDA

- CUDA can manage to read from arbitrary memory addresses.
- CUDA exposes a fast shared memory region (up to 48KB per Multi- Processor) that can be shared amongst threads. This can be used as a user-managed cache, enabling higher bandwidth than is possible using texture lookups.
- Memory accesses are fast and quickly.
- Full support for integer and bitwise operations.
- Supports many of image processing libraries.

IV. SHIP DETECTION ALGORITHMS

1. Sobel Operator

The Sobel operator, also called Sobel Filter, is used in image processing. Sobel operator is used particularly as edge detection algorithms, and creates an image which emphasizes edges and transitions. Sobel operator works on 3x3 pixel windows and has two derivatives one called horizontal derivative (VX) and other called vertical derivative (VY). Hence, the image is divided in to 3x3 windows in order to apply Sobel operator to the image.

VX = [-1 0 1, -2 0 2, -1 0 1]

-1	0	1
-2	0	2
-1	0	1

V_Y = [1 2 1, 0 0 0, -1 -2 -1]

1	2	1
0	0	0
-1	-2	-1

Resultant gradient approximation is given by equation 1

$X = \sqrt{(Vx2+Vy2)}$ …(1)

X is the resultant gradient of image 3x3 window calculated by Sobel Operator.

2. Parzen Window Kernel based Algorithm

The basic idea of the Parzen window kernel method [2] is to utilize the weighted sum of different kernel functions for obtaining the estimation of the statistical distribution. Commonly used kernel functions include the uniform, triangle, cosine, and Gaussian. Here we use the standard normal distribution as the kernel function

□(u) = (1/√2π).exp(-u2/2) …(2)

The corresponding cumulative distribution function (cdf) is given by equation 3.

Φ(u) = (1/√2π) ∞∫u exp(-t2/2)dt …(3)

Therefore, the estimation of pdf for SAR image follows the approximation of the kernel functions as given by equation 4

$$\hat{p}_N(x) = \sum_{j=1}^{N} (1/hN)(x-xj)/hN \quad \dots(4)$$

where x1, x2, . . . , xN denote the samples and are corresponded to the value of pixels in SAR image. N represents the number of sample points. hN (hN > 0) is the bandwidth that indicates the width of the kernel function. From (4), the Parzen window kernel method is actually a mixed distribution by accumulating different kernel functions. The estimation expression of image pdf is obtained by the weighted sum of the kernel functions in samples. Therefore, the characteristic of this method is suitable for the estimation of various complex and unknown pdf, in spite of single peak, multipeaks, regulation, or nonregulation

In equation 4, small hN will make the pdf estimate appear noisy, while big pdf will lead to smooth estimates where important structural features may be missed. The selection of bandwidth hN can adopt several methods, such as the plug-in estimators and data-driven manners. On the other hand, hN should decrease with the increase of N so as to make pˆN (x) be convergence.

3. False Alarm Rate (CFAR) Detection

Assuming that the pdf estimation of SAR image is pˆN (x), we combine equation 4 under the condition that the theoretical false alarm probability of detection is Pfa, and then global detection threshold T is calculated.

Pfa = ∫T∞ pˆN (x) dx …(5)

Let t = (x - xj)/√2 hN

According to the error function and the complementary error function whose expression is

erfc(x)=1-(2/√π)∫0x e-t2 dt …(6)

therefore, Pfa can be written as

$$Pfa = 1/2N \sum_{j=1}^{N} \mathrm{erfc}((T-xj)/(\sqrt{2}\, hN)) \quad \dots(7)$$

The detection threshold T can be finally determined by equation 7. Thus, for a pixel, if its intensity exceeds T, then the pixel is considered to be target point otherwise it is a clutter point.

V. SYSTEM MODEL

The System model of SDS is given in the Fig. 1 below.

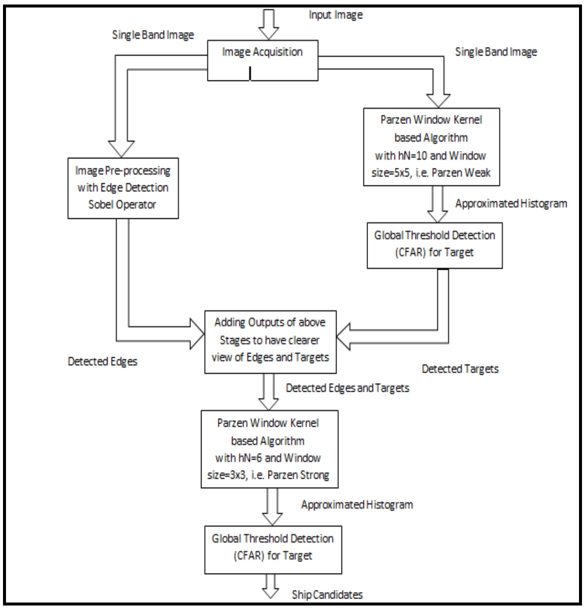


Fig.1 SDS Model for Ship Detection

SDS Model consists of modules as given in above figure and all these modules are implemented in CUDA. The SAR image is loaded by Image Acquisition Module. The loaded image consists of 3 Bands viz. Band 1, Band 2 and Band 3. For Ship Detection there is no need to consider all 3 Bands, so only Band 1 is used for further modules. Edge Detection module calculates Sobel Operator to enhance edges in the image. Parzen Weak Module approximates the histogram in Band 1 and then Output is given to CFAR Module. CFAR calculates global threshold to detect targets. The output of Edge Detection module and CFAR module are mixed/added in next module i.e., Add-Outputs Module. This module outputs image with more clearer view of edges and ship targets. Parzen Strong Module divides images in 3x3 windows and approximates histogram of all windows then merges all approximated histogram to form a single image. Last module CFAR is calculates global threshold on Parzen Strong Output to detect ship candidates. Significance of Parzen Strong and Last Module CFAR is to detect some of missing ship candidates.

VI. EXPERIMENTAL SETUP

SDS is implemented in CUDA Environment in order to detect ship candidates in less time as compared to CPU. In order to achieve this, an experimental setup is required. The setup is as follows-

Table 1.Hardware and Software Requirements

Sr. No.	Pre- requisite	Hardware/ Software Version
1	Operating System	Linux (CentOS 6.0 and above)
2	Image Viewer Software	LeoWorks 4.0
3	Parallel Computing Environment	CUDA 5.5
4	Nvidia Graphics card	Above 1GB
5	Processor	2GHz Or above

1. Image Data Set

Data set consists of Optical Image taken by FORMOSAT-2, image resolution is 2m and file format is GeoTiff. Input image is as shown in Fig.2. Image is downloaded from the website http://www.astrium-geo.com/en/23-sample-imagery.


Fig.2 Original Image

2. Experiments

The image taken by FORMOSAT-2 is downloaded and this image is given input to Image Acquisition Module. Let this image be Input.tif. Image Acquisition Module loads image and separate the bands of the image. For ship detection, there is no need of all bands, so single band is used hereafter in SDS. Let single band image is Band1.tif. Band1.tif image is given input to two modules viz. Edge Detection Module and Parzen Weak Module. Edge Detection Module implements Sobel Operator, image is scanned to detect edges in the images. For Sobel Operator, image Band1.tif is segmented into 3x3 windows and then output is merged to form image Edge.tif as shown in Fig.3 (a). For Parzen Weak,values are set as hN=10 and Window Size=5x5, it’s called Parzen Weak because of greater window size and hN. Band1.tif image loaded to

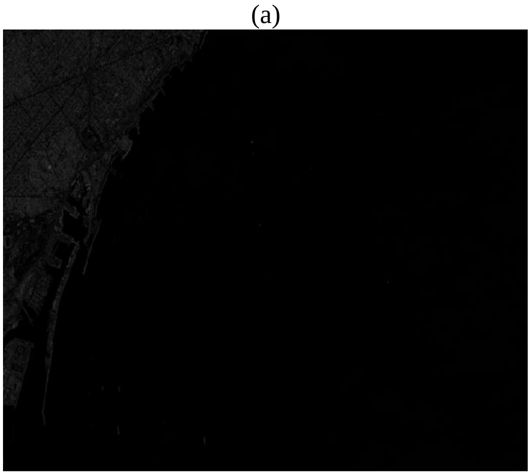
Parzen Weak Module, here histogram of Band1.tif is approximated.

After approximating histogram, global threshold is calculated by CFAR Module. If pixel intensity of approximated histogram image is greater than threshold then the pixel can be a target pixel (i.e., ship or non-ship candidate) or else not a target pixel. Output of this module is Parzen1.tif as shown in Fig.3 (b). Now, Edge.tif and Parzen1.tif given as input to next module where pixel intensities of both images are added to have clearer view of edges and ship targets. Hence, output of this module is Mix.tif as shown in Fig.3 (c). Again Parzen window kernel based algorithm and CFAR are applied to Mix.tif image to get final output which has clear view of ships. Ouptut image is Parzen2.tif as shown in Fig.3 (d).

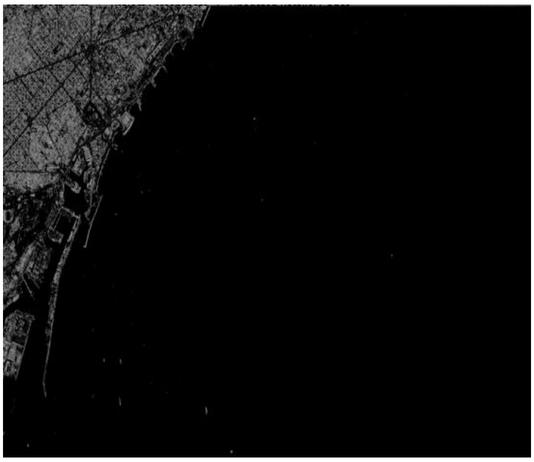
1. Results

Results of above experimental setup are given in Fig.3 these results are module wise as the flow of the SDS advances. Fig.3 (a) is the Output of Edge detection algorithm. Fig.3 (b) is the Output of Parzen window algorithm having h_N=10 and Window size=5x5. Fig.3 (c) is Output of Summation of intensities of above two images. Fig.3 (d) is Output of Parzen window algorithm having h_N=6 and Window size=3x3.

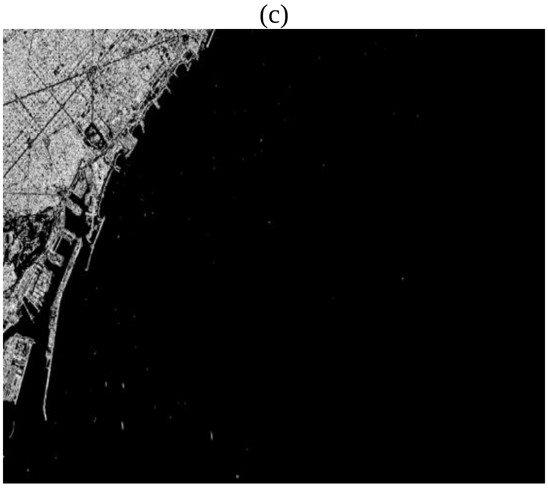
(a)



(b)



(c)



(d)

Fig.3 Ship detection experimental intermediate results (a) Edge detection Algorithm (Sobel Operator). (b) Parzen Window Kernel based Algorithm with hN=10 and Window size=5x5, i.e. Parzen Weak. (c) Mixing output of first and Second Algorithm. (d) Parzen Window Kernel based Algorithm with hN=6 and Window size=3x3, i.e. Parzen Strong

2. Performance Analysis of Sequential Ship Detection System and Parallel Ship Detection System

SDS keeps track of time required by each and every algorithm- CPU code as well as GPU code. The Time required by the algorithms is given in Table 2.

Table 2.Performance Results

Sr. No.	Algorithms	CPU Time in sec	GPU Time in sec
1	Edge detection Algorithm (Sobel Operator)	1.9	0.19
2	Parzen Window Kernel based	290.3	2.27

	Algorithm with hN=10 and Window size=5x5, i.e. Parzen Weak		
3	Mixing output of first and Second Algorithm	0.87	0.99
4	Parzen Window Kernel based Algorithm with hN=6 and Window size=3x3, i.e., Parzen Strong	375.32	2.5
	Total Time in sec	**668.39**	**5.95**

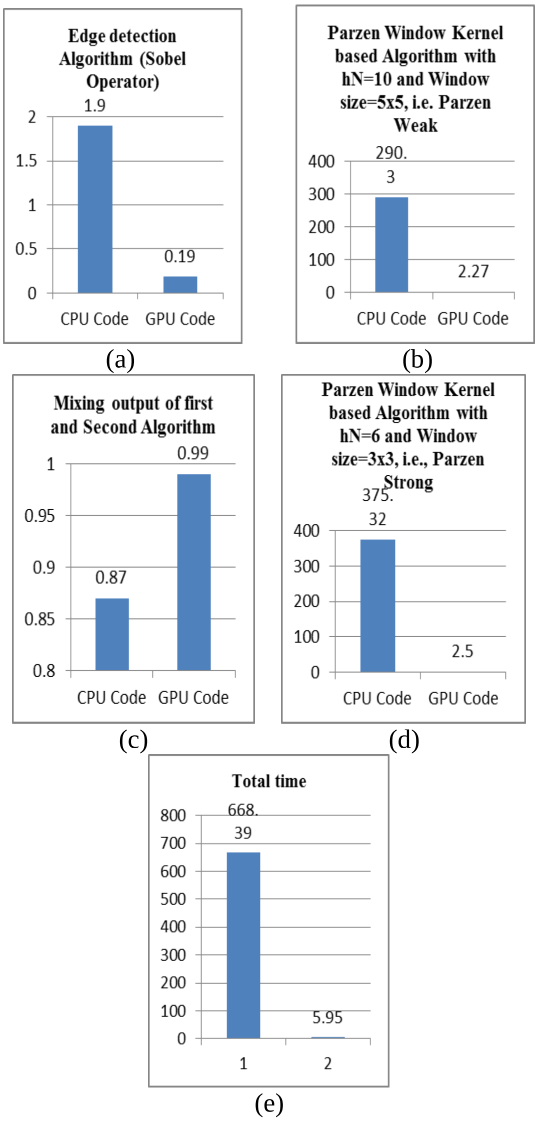


Fig.4 Ship detection performance analysis (a) Edge detection Algorithm (Sobel Operator). (b) Parzen Window Kernel based Algorithm with hN=10 and Window size=5x5, i.e. Parzen Weak. (c) Mixing output of first and Second Algorithm. (d) Parzen Window Kernel based Algorithm with hN=6 and Window size=3x3, i.e. Parzen Strong

Fig.4 (a) is a graph showing CPU time and GPU time for Edge Detection which is 1.9 and 0.19 sec respectively. In the same way Fig.4 (b), (c), (d) shows CPU and GPU time. Fig.4 (e) shows total time required by CPU to detect ship targets and total time required by GPU to detect ship targets. GPU takes total 5.95 seconds and CPU takes total 668.39 seconds.

Speedup(S) is a measure for performance while executing a task. Speedup in context with CUDA is defined as-

Speedup(S) = (Time taken by Serial code to run on CPU) / (Time taken by Parallel code to run on GPU)

Speedup(S) = 668.39/5.95

Speedup(S) =112X

Hence, Ship Detection System (SDS) implemented in CUDA and run on GPU is faster than Ship Detection System (SDS) run on CPU achieving Speedup of 112X.

VII. CONCLUSION

Aiming at ship detection in SAR images, this project has proposed a Parzen-window-kernel based CFAR algorithm. The idea is using nonparametric methods based on Parzen window kernel to estimate the probability density function of SAR image data with high estimation accuracy. The analysis of the detection performance over the typical real SAR images confirms the effectiveness of the proposed algorithm. Till working, from information gathering, the use of probability density function pdf for segmentation of SAR images that enclose oceanic areas with the intention of ships detect is very efficient. Ship detection algorithm was implemented based synthetic aperture radar images; this algorithm is mainly based on local and global threshold techniques.

The presented algorithm can distinguish between ships and look alike. Ship and Non-ship classification accuracies were highly dependent on the feature set selection. The experimental results demonstrate that the proposed segmentation algorithm has the ability to detect ships.

Speedup achieved by SDS implemented in CUDA i.e., run on GPU is 112X as compared to the SDS implemented sequentially. Hence, SDS using CUDA detects the Ships in SAR images at a faster rate.

REFERENCES

[1] Christina Corbane, Layrent Najman, Emilien Pecoul, *A complete processing chain for ship detection using satellite imagery*, International Journal of Remote Sensing Vol. 31, No. 22, 20 November 2010, 5837–5854.

[2] GUI Gao, *A Parzen-Window-Kernel-Based CFAR Algorithm for Ship Detection in SAR*

Images, IEEE GEOSCIENCE AND REMOTE SENSING LETTER, VOL. 8, NO. 3, MAY 2011.

[3] Changren Zhu, Hui Zhou, Runsheng Wang, Jun Guo, *A Novel Hierarchical Method of Ship Detection form Spaceborne Optical Images Based on Shape and Texture Features,* IEEE TRANSACTION ON GEOSCIENCE AND REMOTE SENSING, VOL. 48, NO. 9, SEPTEMBER 2010.

[4] http://www.sandia.gov/~sjplimp/sar.html

[5] http://developer.nvidia.com