Airborne radar clutter simulation using GPU (CUDA)

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ABSTRACT

Radar is an object detection system. Airborne radar is meant to search, detect and track aerial objects. Clutter is an unwanted echo that interferes with the observation of signal on radar screen. This paper discusses the use of GPU and CUDA. Graphic Processor Unit or GPU computing is the use of GPU together with CPU to accelerate general purpose scientific and engineering applications. GPU consists of thousands of smaller, more efficient cores designed for parallel performance. Serial portions of code run on CPU and parallel portion of code run on GPU. GPU offers very impressive architecture for scientific computing on a single chip. CUDA (Compute Unified Device Architecture) is parallel computing platform and programming model created by NVIDIA and implemented by the GPU.

Keywords: Radar, GPU, CUDA

1. INTRODUCTION

Airborne radars work mostly in the state of looking-from-above. Therefore, severe sea and land clutter will produce great influence to target detecting. Radar (Radio Detection and Ranging) is an object detection system which uses radio waves to determine the range, altitude, direction, or speed of objects. It can be used to detect aircraft, ships, spacecraft, guided missiles, motor vehicles, weather formations, and terrain. The radar dish or antenna transmits pulses of radio waves or microwaves which bounce off any object in their path. The object returns a tiny part of the wave's energy to a dish or antenna which is usually located at the same site as the transmitter.

Airborne radar is meant to search, detect and track aerial objects. Airborne radar system designed to detect aircraft, ships and vehicles at long ranges and perform control and command of the battle space in an air engagement by directing fighter and attack aircraft strikes.

Airborne radar is also called as Airborne Early Warning and Control (AWE&C). AEW&C is an airborne radar system. AWE&C units are also used to carry out surveillance, including over ground targets and frequently perform functions similar to an Airport Traffic Controller given military command over other forces. Airborne radar systems can detect aircraft from up to 250 miles (400 km) away, well out of range of most surface-to-air missiles. One AEW&C aircraft flying at 30,000 feet (9,100 m) can cover an area of 120,460 square miles (312,000 km²).

For airborne radars clutter is one of the major performance limiters. The clutter returns enter the radar receiver either through the main lobe of antenna or through the side lobes. The portion of clutter power which enters through the main lobe is called Main Lobe Clutter (MLC) and portion which enters through side lobe is called Side Lobe Clutter (SLC). [1].

The ground unit, called interrogator, transmits coded pulses (after modulation) towards the target. The transponder on the airborne object receives the pulse, decodes it, induces the coder to prepare the suitable answer, and then transmits the interrogated information back to the ground unit. The interrogator/ground unit demodulates the answer. The information is displayed on the display of the primary radar.

The secondary radar unit transmits and also receives high-frequency impulses, the so called interrogation. This isn't simply reflected, but received by the target by means of a transponder which receives and processes. After this the target answers at another frequency.
Various kinds of information like, the identity of aircraft, position of aircraft, etc. are interrogated using the secondary radar. The type of information required defines the MODE of the secondary radar.

2. CLUTTER SIMULATION

2.1 Clutter: Clutter is an unwanted echo that interferes with the observation of signal on radar screen. Clutter refers to radio frequency (RF) echoes returned from targets which are uninteresting to the radar operators [1]. Such targets include natural objects such as ground, sea, precipitation (such as rain, snow or hail), sand storms, animals (especially birds), and atmospheric turbulence. Some clutter may also be caused by a long radar waveguide between the radar transceiver and the antenna. Clutter is considered a passive interference source, since it only appears in response to radar signals sent by the radar. Clutter is detected and neutralized in several ways. Clutter tends to appear static between radar scans on subsequent scan echoes, desirable targets will appear to move, and all stationary echoes can be eliminated. Clutter moves with the wind or is stationary. Two common strategies to improve measure or performance in a clutter environment are:

1) Moving Target Indication which integrates successive pulses and 2) Doppler processing, which uses filters to separate clutter from desirable signals. The most effective clutter reduction technique is pulse-Doppler radar. Clutter may also originate from multipath echoes from valid targets caused by ground reflection, atmospheric ducting or ionosphere reflection/refraction.

Types of Clutter
1) Volume clutter: Weather is a typical volume clutter such as snow, rain.
2) Sea clutter: Disturbing the radar echoes of sea waves
3) Point clutter: Tall buildings, birds and windmill.
4) Surface clutter or ground clutter

In this paper we are considering the ground clutter.
The Clutter which enters through antenna main lobe is very strong return and must be removed during signal processing to reduce false alarms. Main lobe clutter exists in those range bins at which antenna main lobe impacts on to surface.

The spectral width of main lobe clutter is given below:

\[ f_b = \frac{2}{\lambda} \sin(\theta) \cos(\phi) \]

\( \phi, \theta = \text{Azimuth and Elevation} \) \( \lambda = \text{Wavelength} \) and \( V_p = \text{Platform speed} \).

2. Geometry of airborne radar clutter

The three factors that affect the amount of clutter in the radar beam. They are grazing angle, surface roughness and the radar wavelength. Typically the clutter scattering coefficient is larger for smaller wavelength. At intermediate grazing angles, the scattering is similar to scattering from rough surface. Maximum clutter effect is seen with very high grazing angles [2]. The nature of clutter response varies with many factors like grazing angle, spatial location with respect to radar, weather conditions etc. where \( \Delta \theta \) is determined by Azimuth frequency and resolution and \( \Delta R \) is determined by distance resolution. Constant gamma model is used to simulate mean clutter returns.
3. Graphical Processing Unit (GPU)

The term GPU was popularized by Nvidia in 1999, who marketed the GeForce 256 as "the world's first 'GPU'. With the introduction of the GeForce 8 series, which was produced by Nvidia, and then new generic stream processing unit GPUs became a more generalized computing device.

A graphics processing unit (GPU) offers a very impressive architecture for scientific computing on a single chip. GPU is a specialized electronic circuit designed to rapidly manipulate and alter memory to accelerate the creation of images in a frame buffer intended for output to a display. GPU's are more effective than general-purpose CPUs for algorithms [3]. GPU has evolved into a highly parallel, multithreaded, many core processor and very high memory bandwidth. The most commonly used accelerator is the graphics processing unit (GPU) because of its low cost and massively parallel performance. The two most common programming environments for GPU accelerators are CUDA and OpenCL. Modern GPUs are very efficient at manipulating computer graphics, and their highly parallel structure makes them more effective than general-purpose CPUs for algorithms where processing of large blocks of data is done in parallel.

![CPU vs GPU](image)

**Fig 4:** Difference between CPU and GPU

CPUs consist of a few cores optimized for serial processing, while GPUs consist of thousands of smaller, more efficient cores designed for parallel performance. Serial portions of the code run on the CPU while parallel portions run on the GPU.

![GPU Block Diagram](image)

**Fig 5:** Block diagram of GPU

GPU computing is the use of a GPU (graphics processing unit) together with a CPU to accelerate general-purpose scientific and engineering applications [3]. The GPU is especially well-suited to address problems that can be expressed as data-parallel computations. Architecture of GPU is composed of large amount of simple processing units. GPUs have become increasingly attractive for general-purpose parallel computation. Basic unit of work on GPU is thread. GPU have evolved in many real time application because it is easy to implement and can run significantly faster than multi core system.

3.1 QUADRO FX 380

![GPU Quadro FX380](image)

**Fig 6:** GPU Quadro FX380

GPU used in this project is Quadro FX380. Quadro FX380 is used by the artists and designers to create 3D designs from professional platform. It has 50% more performance compared to earlier generations of GPU. Quadro FX380 provides both power efficiency and performance. It will interact with the data much faster to increase in memory bandwidth and makes feasible with the complex computations and designs. It is also used in CAD applications with 900 percentage faster performance. Power saving techniques enables the energy star workstations to efficiently manage the power consumption without sacrificing the performance [9].
Table 1: Quadro Specifications

<table>
<thead>
<tr>
<th>Quadro Specifications</th>
<th>Applicable</th>
</tr>
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<tr>
<td>CUDA Cores</td>
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<td>Memory Size Total</td>
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<td>Memory Interface</td>
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<td>Maximum Power Consumption</td>
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<tr>
<td>NVIDIA CUDA Architecture</td>
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</table>

4. Compute Unified Device Architecture (CUDA)

CUDA Flow: In November 2006, NVIDIA introduced CUDA a general purpose parallel computing platform and programming model that leverages the parallel compute engine in NVIDIA GPUs to solve many complex computational problems in a more efficient way than on a CPU. CUDA comes with a software environment that allows developers to use C as a high level programming language.

CUDA (Compute Unified Device Architecture) is a parallel computing platform and programming model created by NVIDIA and implemented by the graphics processing units (GPUs). CUDA gives developers access to the virtual instruction set and memory of the parallel computational elements in CUDA GPUs [6]. The CUDA platform is accessible to software developers through CUDA-accelerated libraries, compiler directives and extensions to industry-standard programming languages, including C, C++ and Fortran. C/C++ programmers use 'CUDA C/C++', compiled with "nvcc". Nvcc is a compiler driver that simplifies the process of compiling C for CUDA code. CUDA is not just a language but it coordinates the two processing units CPU and GPU. When GPU is occupied CPU should not be pending, CUDA provides such concurrent architecture. CUDA uses global memory i.e., large shared region on memory is called global memory. CUDA assumes a heterogeneous architecture both CPUs and GPUs with separate memory pools.

CUDA architecture is ideally suited for computations that can be run on numerous data elements simultaneously in parallel. This typically involves arithmetic on large data sets (such as matrices) where the same operation can be performed across thousands, if not millions, of elements at the same time. This is a requirement for good performance on CUDA: the software must use a large number of threads. Basic function of CUDA is thread. To use CUDA, data values must be transferred from the host to the device along the PCI Express (PCIe) bus [7].

CUDA Architecture

CUDA Architecture comprises of three basic parts, which help the programmer to effectively utilize the full computational capability of the graphics card on the system. Architecture splits the device into grids, blocks and threads in a hierarchical structure as shown in fig. The CUDA device is suited for computations that can be run on numerous data elements simultaneously in parallel. This typically involves arithmetic on large data sets where operations can be performed across thousands of elements at same time. The support for running numerous threads in parallel derives from CUDA architecture [6].
Grid: A grid is a group of threads all running the same kernel. These threads are not synchronized. Every call to CUDA from CPU is made through one grid. Starting a grid on CPU is a synchronous operation but multiple grids can run at once.

Block: Grids are composed of blocks. Each block is a logical unit containing a number of coordinating threads, a certain amount of shared memory.

Thread: Blocks are composed of threads. Threads are run on the individual cores of the multiprocessors, but unlike grids and blocks, they are not restricted to a single core. Like blocks, each thread has an ID (threadIdx). Thread IDs can be 1D, 2D or 3D (based on block dimension).

5. Results

![Fig 9: Device properties output](image)

![Fig 10: Result of simulation on CPU](image)

![Fig 11: Result of simulation on GPU](image)

6. CONCLUSION

Airborne radar is meant to search, detect and track aerial objects. Clutters are an unwanted echo that interferes with the observation of signal on radar screen. Removing many clutters in radar may lead to computational problem. These computational problems are solved by GPU, because GPU solves computational problems more efficient way than CPU.
GPUs are highly parallel, multi threaded, many core processor and very high memory bandwidth. CUDA is parallel computing platform and programming model created by NVIDIA and implemented by the GPU. CUDA comes with a software environment that allows developers to use C as a high level programming language. From the above results performance is increased and time is reduced from CUDA programming on GPU device compared to CPU device.

**EQUATIONS:**
The spectral width of main lobe clutter is given below:

\[ f_d = \frac{2 V_p}{\lambda} \sin(\theta) \cos(\phi) \]

\( \phi, \theta = \) Azimuth and Elevation \( \lambda = \) Wavelength and \( V_p = \) Platform speed.

The clutter return power of the airborne radar is given by the equation

\[ P_{cr} = \frac{C(\alpha, \phi) C(\beta, \phi)^2 P^2 R_{target}(\Phi) \beta_t}{(4\pi)^3 (\text{Losses})^2} \]

The total Clutter power at a Range Bin is given by: Clutter power at a Range Bin = \( \sum C_p \left( f_d \phi(R) \right) \)

**REFERENCES**

**AUTHOR**
Priyanka A P During 2004-2008, she studied in Electronics and Communication Engineering in Mysore, and received the B.E. degree from VTU University in 2012, during 2012 – 2014 studied Masters in VLSI and Embedded Systems from VTU Extension Centre, UTL Technologies Ltd, and M.Tech project was carried out in Development Research and Defense organization (DRDO), (LRDE), Bangalore.

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