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Agile Condor: Pod Based Computing

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Abstract

The Agile condor is a scalable and high performance embedded computing system increases computational capability within the restrictive size, weight and power constraints of aircraft system external pod payload. The inside pod is a lightweight thermally efficient industry standard 3U conduction cooled chassis. It's support requirement board and interface hardware. Agile condor brings high performance computing closer to neuromorphic computing and autonomous system operation.It's objective is enable scalable real-time processing for intelligence surveillance and reconnaissance (ISR) missions, Weigh less than 60 pounds, Consume less than 500 Watts of power. It Deliver over 15 GFLOPS/Watt (enabled by GPUs).Develop a rugged pod-based external payload. Design to support Group 3-5 DoD unmanned aerial systems (UAS).Agile Condor will support a rapid response to unexpected challenges. Agile condor software is designed in real time processing and support post processing in air, ground and sea. It uses neuromorphic techniques. It capabilities will be demonstrated using processing algorithm with SAR(Synthetic Aperture Radar) algorithm. In agile condors components are uses processing and computing different that is a scalable computing, autonomous operation, information processing, massive analytics, SAR,MTI etc.

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Keywords: *Scalable Computing, High Performance Computing, Pod-based Computing, Autonomous Operations, High- Performance Embedded Computing, Information Processing, Synthetic Aperture Radar, Moving Target Indication, range Compression, Range Migration, Azimuth Compression.*

I. INTRODUCTION

Agile Condor provides a scalable and embedded HPC system based on open industry standards that will increase computational capability within the restrictive size, weight, and power (SWaP) constraints of external pod payloads. The system was designed to support Group 5 DoD unmanned aerial system (UAS) platforms, with a goal of ultimately meeting further constrained requirements for the smaller, Group 3 DoD UAS platforms.

In order to meet these requirements, the initial system will weigh less than 60 pounds and consume less than 500 W when fully operable. The chassis dimensions for Agile Condor are limited by the size available within the selected pod discussed in Section III. Rugged hardware along with the recently developed Airborne Wide Area SAR Processing (Air WASP) software framework will deliver an estimated 15 GFLOPs/W.

Agile Condor's software is designed for real-time processing and can also support post-processing in air, ground and sea scenarios. This scalability helps meet the needs of both traditional and future signal processing requirements such as emerging neuromorphic computing techniques. In particular, ISR missions face elevated demands in order to effectively operate in contested and challenged environments.

To maximize the effects of the ISR mission, massive amounts of data must be processed in real-time and the resulting data must be analyzed promptly to determine the current state of the area of interest. To meet these needs, the Air Force Research Laboratory Information Directorate proposes a two-part solution. (1) An HPEC system that integrates (2) bio-inspired embedded computing hardware to deliver a set of autonomous sensing capabilities.

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II. BACKGROUND

Research and development being performed at the Air Force Research Laboratory's (AFRL's) Information Directorate is leading the way by providing a scalable, reconfigurable, embedded processing capability to ingest raw sensor data, process the data into information, and distribute the products to the war fighter. The Information Directorate's work is being performed Wider two projects, Airborne Wide Area SAR Processing (AirWASP) and Radiofrequency Adaptive Persistent ISR Data (RAPID) Link.

The Air WASP project is focused on the processing capability, and the RAPID Link project is developing the data air-to-ground downlink portion. This paper addresses the requirements, generation, processing needs, and system design for Air WASP. Embedded computing systems fulfill a range of mission needs and can be used in a variety of situations that are constrained by SWaP. The development of embedded systems has diversified to include meeting changing requirements.

Due in part to the drive for development of HPC systems for military ISR missions, the embedded computing industry has invested increasing resources toward developing HPEC systems. For example, without the use of an HPEC system, a typical mission collecting 100 TB of sensor data could process and analyze only 0.09% of that data with current downlink capabilities. The need for processing onboard and close to the sensor is increasingly prevalent and necessary in military applications.

III. DESIGNING THE SYSTEM

AirWASP is scalable across a range of requirements. However, for design purposes, the performance parameters of the chosen demonstration vehicle, i.e., the Gotcha II system, were used. As shown, the Gotcha II program has both an objective goal and a threshold goal.

The Air WASP system was designed to meet the threshold goal; scalability was also considered during development in order to fulfill future needs of the objective goal.

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Table 1.Key Gotcha II Performance Parameters

Parameter	Objective	Threshold
Area of coverage	20-km diameter	1 0- km diameter
Surveillance area	3 1 4 km2	78.5 km2
X-band resolution	0 . 3 m	0 . 5 m
U H F resolution	1 m	3 m
Frame rate	4 frame/s	1 frame/2s

The AirWASP system is a heterogeneous system composed of state-of-the-art CPUs and GPGPUs that fulfill previously mentioned requirements. The system consists of FEPs, a 40-GbE switch (GbE is equal to 1-gigabit/ s Ethernet, i.e., Ethernet capable of transmitting data at the line rate of 1 billion bit/ s), and six compute nodes. The block demonstrates the framework for processing this particular problem; its versatility allows adjustment of the number of compute nodes to accommodate additional SWaP and mission constraints.

The data flow from the Gotcha II onboard processor requires that an FEP be included in the system, as previously mentioned. The FEP provides a 1 0-s buffer and does limited processing of data prior to distribution to the compute nodes. The primary sources of computation for the AirWASP system are the six compute nodes, illustrated to the right in Figure 2. Each compute node consists of one Intel E-2690 high-performance server equipped with three Nvidia Tesla Kepler K20 GPGPUs.

The use of GPGPUs for signal analy sis has become increasingly popular, as they diversify from high-level graphical imaging, such as that used in gaming, to general-purpose computing. GPGPUs are viable when parallelization of tasks is possible. Nvidia's Compute Unified Device

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Architecture programming model is especially useful in image processing with the use of the back projection algorithm as it takes full advantage of parallelization.

GPGPUs were also chosen as the primary compute source for the SAR data given the high computational requirement. This was first demonstrated with the Video SAR project in 2010 and is now being used in a somewhat different overall architecture in AirWASP.

The most recent GPGPU on the market at the time of development, which was chosen for this project, was the Nvidia Tesla Kepler K20. The K20 provided a significant improvement over previous Nvidia GPGPU architectures used in AirWASP predecessors, such as the Nvidia C2050 GPGPUs used in the VideoSAR project, with a theoretical single-precision peak performance of 3.5 Tflop /s, far surpassing any CPU on the market.

Each compute node is capable of achieving 13 Tflop / s single precision and consumes approximately 1 000 W. To stay within power constraints and meet the processing requirements, six compute nodes are used.

The onboard computing systems place a greater stress on the SWaP of the system. Based on the available space for the projected aircraft to be used by the Gotcha II program, SWaP constraints imposed on the AirWASP system are 27 rack units, 400 pounds, and 8000 W, respectively. While the AirWASP system will initially be flown on a manned aircraft, the flexibility to reorganize the framework will allow the system to be flown on more SWaP-constrained platforms, such as may be the case with unmanned aircraft.

A. Software and Data Processing

Instead of developing information system technology provides capabilities and options through a new and innovative framework that allows a rapid response to changing requirements-providing a truly robust and agile solution. Specifically, in our approach, hardware components such as CPUs and GPGPUs are linked to provide flexibility and basis for a specific task, e.g., a particular surveillance product, the and enhanced operation through interlinked and configurable I / O connections and software components. Furthermore, each component is robust in that the configurations provide varied and multiple data I/O streams.

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The advantage to this component model is the configurability to reorganize the system's underlying operational framework in order to optimize processing-based needs and pertinent me transformation, which includes information on the raw data, the finished information products, and the system constraints, e.g., time, power, and storage.

Therefore, the challenge addressed is understanding how to properly and effectively distribute each algorithm so as to minimize data movement and maximize processing throughput. These efforts expand the utilization of the code developed across multiple platforms, algorithms, system configurations, and ultimately, end-user needs.

To test these capabilities, a full back projection SAR algorithm was implemented. Many SAR image formation implementations avoid this algorithm because of the computational burden. For an N by N pixel image, with Np pulses of compressed range data, the number of operations is proportional to

Operations = N2 N p

On the order O(Nl). While this puts an upper bound on the computational complexity, the value in pursing this algorithm is that it is processing intensive and applicable to various complex remote sensing and military applications. When considering a real-time case, if the processor is capable of back projecting a single pulse of data (Np = 1), to N by N pixels, at a rate less than or equal to one pulse repetition interval (PRl), the number of operations is on the order of O(N2).

The total number of operations has not changed, although since we are processing in real time, we are constrained by the PRl. In exchange, the image formation is more robust, and it affords the opportunity to perform terrain height correction on the fly. In addition, for longer PRls, assuming proper data support, techniques such as azimuth presuming may be employed to reduce the input data rate by down sampling azimuth data using a digital, low-pass filter.

These are specific examples of processing needs that are analyzed, as part of the framework, to aid in maximizing effective utilization of both the hardware and the software available.

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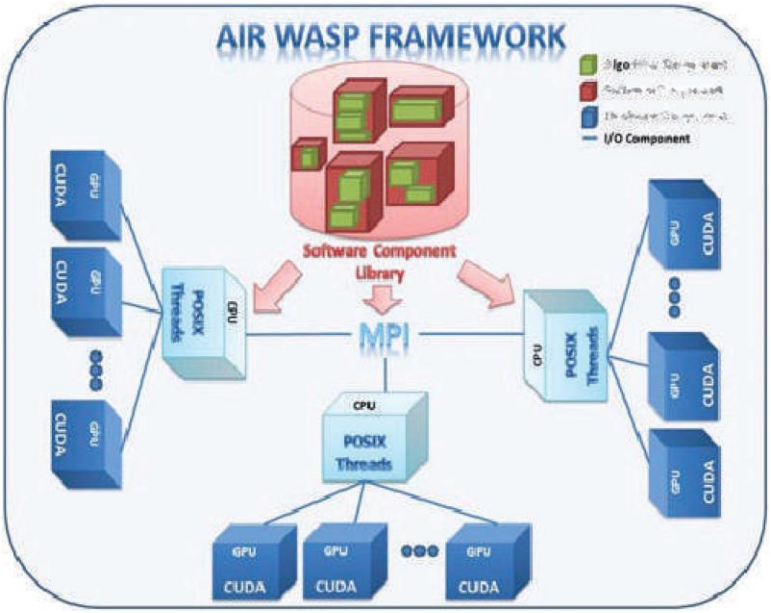


Fig. The Air WASP framework

IV. IMAGE FORMATION

A. Geometry of SAR system

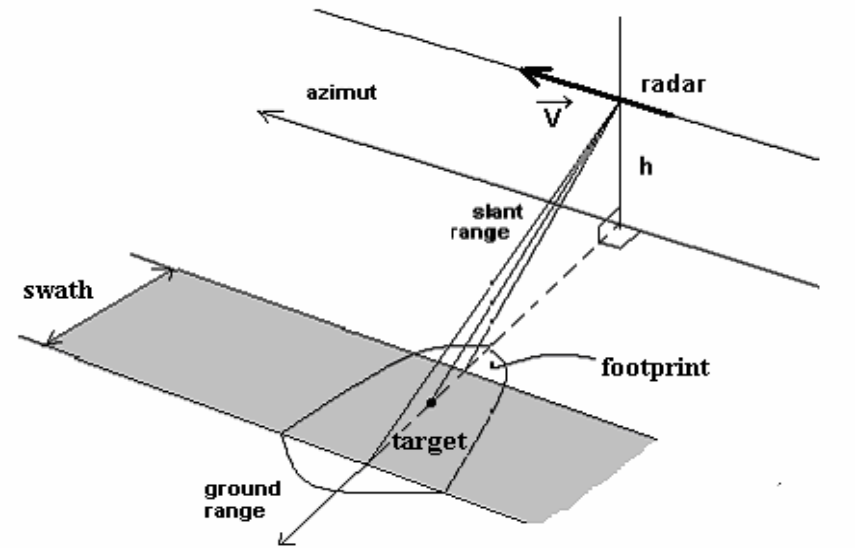


Fig. Side-looking strip-map SAR geometry

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There are basically three operating modes of SAR syste: Stripmap scan and spot. The most popular is probably the strip mode. In this case, the radar antenna point along fixed position direction with respect to the flight platform path, and the antenna footprint covers a strip on the illuminated surface as platform moves.

The radar transmits pulses at the pulse repetition frequency, PRF, and for each pulse the backscatter return from the ground is sampled in range at the analog to digital (A/D) sampling frequency. The radar operation is coherent, which means that both the return magnitude and phase (with respect to the transmitted signal) are sampled. For each range sample the in-phase and quadrature values (I and Q) are stored. The raw data file is thus a two dimensional array of complex values (with I as the real part and Q as the imaginary part). This two-dimensional data set is then processed to form an image.

B. Pulse Compression

Let us consider a radar system transmitting at microwave frequency, electromagnetic pulses of time duration Δt . The sensor range resolution is given by:

$$\Delta R = c.\Delta t/2$$

Range resolution for a given radar can be significantly improved by using very short pulses. Unfortunately, using short pulses decreases the average transmitted power. Since the average transmitted power is directly linked to the receiver SNR, it is often desirable to increase the pulse width while simultaneously maintaining adequate range resolution. This can be made possible by using pulse compression techniques.

Pulse compression allows us to achieve the average transmitted power, while obtaining the range resolution corresponding to a short pulse Range resolution for a given radar.

C. SAR Processing

SAR processing is the transformation of raw SAR signal data into a spatial image. In its most abstract form, this is the process of performing a frequency domain correlation of the received signal with a 2-D system transfer function. In practice, this process is performed in several 1-D steps, including range compression, range migration, and azimuth compression. These three processing steps are each displayed graphically in figure.SAR Processing.

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D. Data Format and Required Parameters

The CEOS-format SAR raw data nominally consists of a volume Directory File, SAR Leader File, Raw Data File, and a Null Volume File. The Volume Directory File describes the arrangement of the data on the storage media. The SAR Leader File provides pertinent information about the specific SAR data set: Raw Data File size, spacecraft height and velocity, scene center latitude, longitude and time of acquisition, etc.

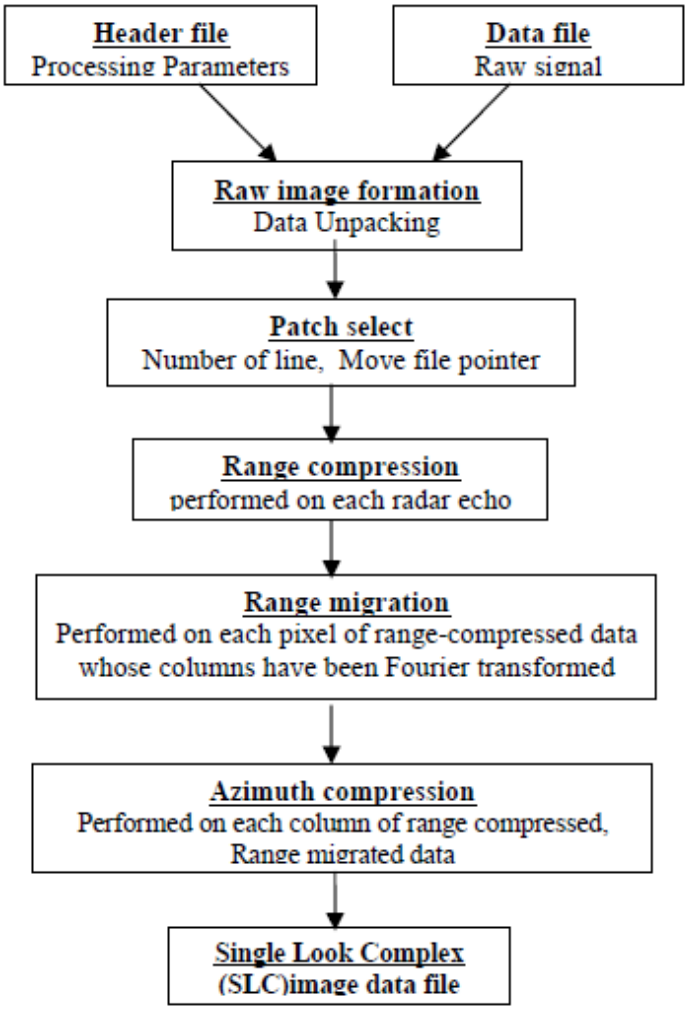


Fig. SAR Processing

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The first step performed by the SAR processor is to read in the SAR processing parameters. Sufficient parameters for SAR processing of ERS data and some representative values are shown in Table 1. The next step is to read in a block of data whose rows correspond to an area larger than the radar footprint in the along-track direction and whose number of rows is a power of 2 for efficient use of Fast Fourier Transforms (FFTs). When image formation is processed directly from raw data, only a few parameters are required.

- Platform state vectors
- Time of reception for each pulse
- Slant range offset (corrected for internal delay in the radar)
- Reference squint angle.

In conjunction with other processing parameters, e.g. processing window offset. The SAR focusing additionally requires:

- Carrier frequency
- Sampling frequency
- Knowledge of pulse encoding, e.g., chirp length, and bandwidth.

Table 2.SAR Processing Parameter

Processing Parameter	
Range pulse code specifier	Linear FM Chirp
Range sampling rate fs	18.9624680 MHz
Range pulse length τp	37.120 microseconds
(Chirp) phase coefficient Quadratic term K	4.17788e+11 Hz/sec
Radar frequency	5.300 GHz
Radar wavelength λ	0.0566660 eters
Pulse Repetition Frequency	1679.9020 Hz

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(PRF)	
Incidence angle at first range pixel (at mid-azimuth)	19.386 degrees
Quantization per channel I & Q	5 bits
fd 1	326.23 Constant coefficient of Doppler centroid frequency
fdd 1	0.0 Linear coefficient of Doppler centroid frequency
fddd 1	0.0 Quadratic coefficient of Doppler centroid frequency

CONCLUSION

The Air WASP framework leverages enabling technologies to aid in persistent surveillance missions onboard a manned aircraft. Our SAR image algorithm is currently available only for ERS images, and its image reconstruction procedure is 2-stage FFT (Fast Fourier Transform)-IFFT(Inverse Fast Fourier Transform) method. This method first executes range compression in Fourier domain, the next step is to execute azimuth compression in Fourier domain. It is the most standard method of SAR image reconstruction. In this above presentation of SAR image formation, number of approximations and simplifying assumptions were introduced. These make the formulas used in signal processing geometrically inexact and so require corrections, usually to the pixel locations of the processed data. One such resampling requirement is to obtain uniform ground range sample spacing. By digitizing uniformly in time (at 18.96 MHz), the samples are uniformly spaced in slant range at about 7.9 m, which implies ground range spacing that varies from 24 m to 18 m with increasing range. Thus the nominal 12.5 m range pixel size represents an interpolated resampling.

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