Playback system designed for X-Band SAR

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Abstract. SAR (Synthetic Aperture Radar) has extensive application because it is daylight and weather independent. In particular, X-Band SAR strip map, designed by Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, provides high ground resolution images, at the same time it has a large spatial coverage and a short acquisition time, so it is promising in multi-applications. When sudden disaster comes, the emergency situation acquires radar signal data and image as soon as possible, in order to take action to reduce loss and save lives in the first time. This paper summarizes a type of X-Band SAR playback processing system designed for disaster response and scientific needs. It describes SAR data workflow includes the payload data transmission and reception process. Playback processing system completes signal analysis on the original data, providing SAR level 0 products and quick image. Gigabit network promises radar signal transmission efficiency from recorder to calculation unit. Multi-thread parallel computing and ping pong operation can ensure computation speed. Through gigabit network, multi-thread parallel computing and ping pong operation, high speed data transmission and processing meet the SAR radar data playback real time requirement.

1. Introduction
With the development of the theory of microwave remote sensing imaging, synthetic aperture radar (SAR) has a wide range of applications. Compared with the optical imaging, SAR imaging is not influenced by the weather conditions. With high resolution and wide swath, airborne X-band SAR radar, compared with spaceborne SAR, is more mobile, flexible and suitable for high-precision mapping and is an important observations instrument which is used to Earthquake Disaster Mitigation and so on. In accordance with the predetermined trajectory movement, airborne SAR radar transmits broadband linear FM signal and receives the ground reflected echo signal, which is stored in the electronic disk through AD sampling quantify system converting into raw signal. X-band SAR radar playback system via network to read radar sampling data, generates zero-level data products according to data product and quick-look image format.

The most common SAR imaging algorithm includes Range-Doppler (RD) [1][2] and Chirp-Scaling (CS). The RD algorithm regards radar echo signal as independent linear FM signal at range and azimuth, which can be matched filtering at each direction to accomplish quick-look image. Compared with the CS algorithm, RD algorithm reduces the FFT operation, and improves the processing efficiency, which is more suitable for quick-look imaging.

In this letter, playback [3] system converts the radar raw echo data recorded on electronic disk into standard format level-0 data product, and generates corresponding quick-look image. These data products...
and quick-look images help us extract target information quickly, and save time for the subsequent image processing tasks. It improves the efficiency of the whole set of airborne X-band SAR system operating in emergency situation. Ping-pong design, used in input data buffer of the playback data system, can optimize the entire system, so as to ensure high efficiency of each processing module of the whole system. RD algorithm is used to accomplish quick-look imaging design. Multi-threaded parallel processing technology is to improve the overall efficiency of imaging processing structure.

2. Design function of playback system
SAR radar transmits chirp signal, and receives ground reflection echo, which is recorded in electronic disk. The electronic disk, which capacity is up to 1.5 GB, supports SAR system working four hours. The playback system of the airborne X-band SAR, connecting electronic disk to imaging system, provides level-0 raw signal data products and corresponding quick-look images. According to whole structure of airborne X-band SAR radar system, there are four main design features of the playback system.

1. Instruction control of electronic disk. When SAR completes data recording, establishing network communication between the playback system with electronic disk, to achieve data directory inquiries, reading the original echo sampling data via gigabit network, deleting data recorded in the electronic disk.

2. The quality check of the original echo signal. When the SAR is at work, there may be some reasons that can result to data error in electronic disk, so we should mark them. For example, the counter of pulse recurrence frequency (PRF) should increases in accordance with the order. However, due to the instability of the electronic equipment in the process of high-speed operation, the count will produce hopping. These errors will be recorded into a separate file for marked.

3. Provide level-0 data product. Converting raw echo data to product, according to X-band SAR three work modes that are 0.5 m, 1 m and 3 m resolution. There is half of the synthetic aperture overlap in two adjacent data products.

File structure of level-0 data product is composed of six parts, which are header data, parameter data, calibration data, DEM data, radar auxiliary data and X-band radar data. Except for the radiometric correction vectors, auxiliary data and X-band radar data, each field of the four data sections is 50 characters long, and written in ASCII. The field descriptor is left justified in the 50 character string, followed by the value for that descriptor right justified in the same 50 character string.

In header data, we provide the description of all the data section, about number of character strings occupied by each section. The second data record is the parameter header. The parameter data contains information specific to the scene and the radar system. In the case of calibrated radar data, calibration section will follow the parameter. The calibration data consists of records for compressed polar metric data, radar system calibration data, and pattern data of antenna. DEM section contains information specific to the elevations and geo-location of the image. Auxiliary data provides radar system status and parameter data when the system is working in the region.

4. Quick-look imaging. Imaging processing uses the RD algorithm [4], which ignores the range migration, and filter to reduce the sampling frequency. Although it will decrease the resolution of the image, but can significantly reduces the amount of calculation of the FFT at range and azimuth processing, improves the processing speed at finally.

3. Process flow and algorithm
1. System structure and ping-pong cache.
Using a high-performance server achieves structure of playback system. Server, equipped with 8 CPUs and 64G memory space, supporting 64 parallel processing threads, has powerful computing capacity and data storage space. The entire playback system module consists of four parts:

(1) Reading Radar original echo data module.
(2) Quick-look imaging module.
(3) Data checking.
(4) Providing level-0 data product.

Playback system connects electronic disk and subsequent imaging processing system by
gigabit network separately. The data transmission speed in the network restricts processing speed of the entire playback system. Playback system applying ping-pong cache and parallel technology completes software design framework, improving the efficiency of the processing. Fig. 1 shows workflow of the playback system.

**Figure 1.** Workflow of the playback system

Building two data storage space in the server, the size of each data space is determined by SAR working mode. When radar echo data is sequentially stored in storage space, the server completes the data processing in another storage, which includes data checking, quick-look imaging and level-0 data product.

2. **Range - Doppler algorithm**

Range - Doppler (RD) algorithm is a basic SAR digital imaging algorithm. Based on matched filtering and pulse theory, the algorithm turns two-dimensional SAR imaging processing at range and azimuth, into two one-dimensional separable processing at each direction approximately. The basic step is making range compression for each echo pulse at first, then in the RD field, eliminating the coupling between range and azimuth orientation, caused by range migration, and finally completing focusing process at azimuth.

The time domain and frequency domain mixed method is an accurate RD algorithm. It conducts time domain processing at range and frequency domain processing at azimuth. Range migration correction in the frequency domain. X-band airborne aviation SAR works in side looking strip scanning mode, so it can obtain satisfactory results in the case of small range migration.

Fig. 2 shows the specific implementation of the algorithm, which is in order to complete digital pulse compression (DPC) at range, range walk correction, FFT at azimuth, range curve correction, matched filtering and IFFT at azimuth.
Parallel computing can speed up processing, solving the same problem in a shorter time or at the same time solving more complex problems, and need much more amount of calculation. Parallel computing can be used to complete the high-performance serial computing tasks at a lower cost.

Open memory parallel programs running as serial program at beginning. There is a main thread, and then opens up the parallel thread regions and creates a number of threads. Each thread is executed by a CPU core to speed up the processing speed. When reaching the end of the parallel region, the threads enter sleep or demise, and main thread continues implementing the program.

The playback system, when conducting quick-look imaging with RD algorithm, divides the FFT operation into 60 threads to run at the same time. The calculation time is shortened. The more resources CPU consumes, the more effective parallel operation is. However, due to the synchronization control, CPU communication consume and occupancy time, parallel efficiency can never reach 100%. More than 90%, the parallel processing is considered successful.

4. Processing result of playback system
By multi-threaded parallel computing, quick-look imaging with RD algorithm, and utilizing server’s superiority of the multi-core CPU processing advantages, we can reduce computation time of Fast Fourier Transform (FFT), which is the most calculation part of imaging process. Multi-threaded parallel computing, that improves processing efficiency of the entire imaging above 90%, ensure that the speed of the imaging processing is higher than reading speed from electronic disk. Therefore, processing speed of the playback system is equivalent to data transmission speed of the network. Because network utilization reaches 90%, and data transmission speed of the network is equal to the speed of SAR receiving echo data.

5. Conclusion
Airborne X-band SAR is applied to emergency field, such as earthquake, flood. These situations propose time requirements to provide SAR data and image. Playback system, with multi-thread parallel processing technology, ping-pong cache and RD imaging algorithm, generates level-0 data products and quick-look images. It provides support for the following precise imaging and
target information extraction.

6. Reference

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