A SAR PARALLEL PROCESSING ALGORITHM AND ITS IMPLEMENTATION

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ABSTRACT:

With the development of SAR processing techniques, high image precision and high real time rate have becoming an important index, especially on military filed. This paper presents a medium grained parallel processing algorithm for SAR imaging. In this parallel processing algorithm, every processing stage is done in parallel, and the degree of parallelism is task-level. It is fit for the parallel computer with good communication capacity. The experiments on DAWNING3000 shows this parallel processing algorithm can get good result on real time rate and processing efficiency.

1. INTRODUCTION

High image precision and high real time rate have becoming more and more important in SAR area, especially on military filed. High image precision means more complicated algorithm and more computing time, but the request for real time rate limits the processing time, so we must find way to solve this problem. Parallel processing technique gives the way to achieve high image precision and high real time rate.

Parallel processing is different from sequential processing: the same parallel algorithm on different parallel computer the efficiency will be completely different. To gain high processing efficiency, the SAR parallel processing algorithm must be proper with the parallel computing system's hardware characteristics. DAWNING3000 parallel computer is a common scalable supper computing system. It is a cluster system based on distributed memory and message passing architecture. There is high-speed communication network between DAWN3000's computing nodes, so it has good communication capacity. This paper presents a medium grained parallel processing algorithm based on chirp scaling algorithm, and high efficiency and real time rate are obtained on DAWN3000.

2. CS ALGORITHM OVERVIEW

Now chirp scaling (CS) algorithm [1-3] has become an important SAR imaging algorithm. In classical range/Doppler(R/D) algorithm, a space-variant interpolation is needed to compensate for the migration of signal energy through range resolution cells. CS algorithm requires only complex multiplies and Fourier transforms to implement and avoids the interpolation, yet performs range cell migration correction accurately.

After demodulation, the point scatterer response is

$$pp(t\,,t;r) = a(t,r)s_0(t - \frac{2R(t;r)}{C})$$
$$\cdot \exp\{-j\frac{4p}{l}R(t;r)\}$$

where $R(t;r) = \sqrt{r^2 + v^2t^2}$ is the instantaneous slant from target to radar. t is range direction time, t is azimuth direction time,

In range signal/Doppler domain, we exploit chirp scaling principle to do curvature equalization. The chip scaling phase multiplierF_1 is

$$\Phi_1(t\,,f;r_{ref}) = \exp\{-jpK_s(f;r_{ref})$$
$$C_s(f)[t - t_{ref}(f)]^2\}$$

where

$$t_{ref}(f) = \frac{2}{C}r_{ref}[1 + C_s(f)]$$

$$C_s(f) = \frac{1}{\sqrt{1-(\frac{lf}{2v})^2}} - 1$$

$$K_s(f;r) = \frac{K}{1 + Kr\frac{2l}{C^2}\frac{(\frac{lf}{2v})^2}{[1-(\frac{lf}{2v})^2]^{3/2}}}$$

After chirp scaling phase multiplying, range cell migration correction and range focus, including secondary range compression are done by multiplying F_2 in two dimensional frequency domain

$$\Phi_2(f_t\,,f;r_{ref}) = \exp\{-jp$$
$$\frac{f_t^{\,2}}{K_s(f;r_{ref})[1 + C_s(f)]}\}\cdot$$
$$\exp\{j\frac{4p}{C}f_t r_{ref} C_s(f)\}$$

At last azimuth compression and residual phase compensation are done in range image/Doppler domain, the required multiplier is F_3

$$\Phi_3(t\,,f) = \exp\{-j\frac{2p}{l}ct[1-[1-$$
$$(\frac{lf}{2v})^2]^{1/2}] + jq_\Delta(f;r)\}$$

where

$$q_{\Delta}(f;r) = \frac{4p}{C^2} K_s(f;r_{ref})[1 + C_s(f)]$$

$$C_s(f)(r - r_{ref})^2$$

3. SAR PARALLEL IMAGING ALGORITHM

Parallel processing for SAR imaging is the way to achieve high real time rate. There are four types parallel computer: the symmetric multiprocessor (SMP), the massively parallel processor (MPP), the cluster of workstations (COW), and the distributed share memory (DSM) multiprocessors. DAWN3000 belongs to COW and each computing node is a four-CUP SMP. The computing nodes of DAWN3000 are connected by high-speed network, so we must balance the computing capacity and communication capacity. This paper presents a medium grained parallel imaging algorithm (see Fig. 1).

In this parallel processing algorithm, every processing stage is done in parallel, and the degree of parallelism is task-level. The reason of this partitioning is every azimuth data line or range data line is independence, so we can partition the whole data block into many data strips, and send every computing node one data strip. This allocation scheme can balance the workload and minimizes overhead.

Suppose the raw data block size is M×N and the number of processors is p. We divide the raw data block into several data strips along range direction, the number of strips is p and the size is [M/p]×N , so every computing node can get one data strip. Let us focus on processor P_1. Now processor P_1 have its own data strip ([M/p]×N), first we do local data transpose and data exchange among nodes, after this the data strip on processor P_1 becomes M×[N/p], so we can do azimuth FFT and chirp scaling multiplying, then we do the second local data transpose and data exchange, now the data strip on processor P_1 is [M/p]×N and we can do range processing at this time, at last we do the third local data transpose and data exchange, now the data strip on processor P_1 is M×[N/p] and we can do azimuth processing.

There are three times matrix transpose, so the data exchanging among nodes is inevitable. In the beginning the matrix element [i , 0], [i , 1], -[i , n-1] are stored in processor Pi , after transpose matrix element [i , 0] belongs to P_0 and [i , 1] belongs to P_1 and so on. In this procedure every processor will send different data to the other processors and receive data from the other processors.

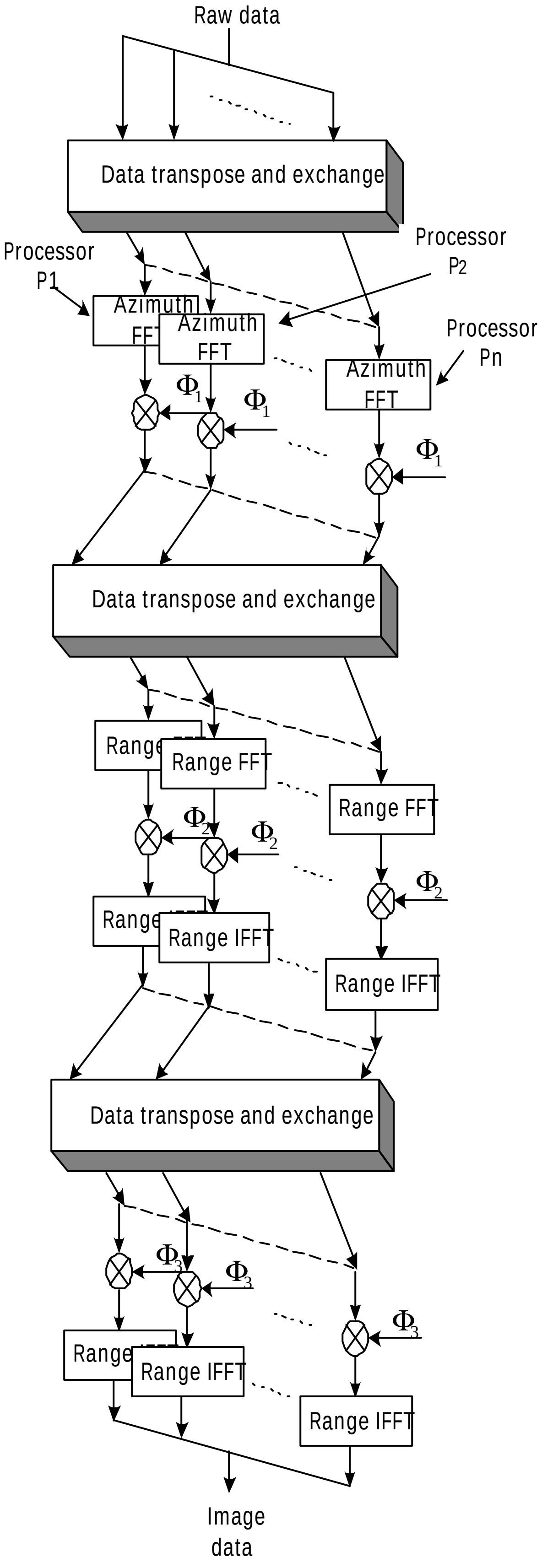

Fig.1 Block Diagram of Medium grained parallel imaging algorithm

4. IMPLEMENT ON DAWNING3000

We use simulative SAR raw data to implement parallel processing on DAWNING3000, the raw data size is 16384× 16384. The parallel program is written on PVM software platform and we use mathematic library on DAWNING3000 to do FFT.

The features of DAWNING3000 parallel compute used in our experiment are showed below:

No. nodes	16
No. processors	64
Processor type	375MHz IBM Power3-II
Memory size per node	2 GB
Cache per processor	4 MB

The experiment result lists in table1.

Table 1 Parallel Processing Result

No. nodes	8	8	16	16	16
No. processors	16	32	16	32	64
Computing Time(s)	78	40.7	77.6	38.3	24.1
Total time	114	75.6	114.8	85.5	64.7
Efficiency	0.97	0.93	0.97	0.98	0.78

Note: Total time include the time of read raw data and save image data.

5. ANALYSIS AND CONCLUSION

In the medium grained parallel imaging algorithm, the computational workload W is fixed (equals to all computation to process one block raw data). As the number of processors increases, the fixed workload is distributed to more processors for parallel execution. We can calculate the speedup and efficiency based on Amdahl's law.

Assume the workload W can be divided into two part $W=W_s+W_p$, where W_s is the part must be executed sequentially, W_p is the part can be executed by n nodes simultaneously, and W_o is overheads, the speedup is

$$S = \frac{W_s + W_p}{W_s + \frac{W_p}{p} + W_o} \qquad (1)$$

Assume W_s is f percent of W ($f = \frac{W_s}{W}$), and W_p is (1-f) percent of W ($1-f = \frac{W_p}{W}$), the speedup in Eq.(1) becomes

$$S = \frac{p}{1 + f(p-1) + p \cdot \frac{W_o}{W}} \qquad (2)$$

In the medium grained parallel imaging algorithm, all computation can be executed in parallel, so f=0, and Eq. (2) becomes

$$S = \frac{p}{1 + p \cdot \frac{W_o}{W}} \qquad (3)$$

So the efficiency E is

$$E = \frac{S}{p} = \frac{1}{1 + p \cdot \frac{W_o}{W}} \qquad (4)$$

From Eq. (4) we can get the conclusion: the performance is limited by the overhead. The main overhead of this algorithm is the collective communication, so increase the parallel computer's communication capacity can increase the efficiency. In our experiment on DAWNING3000 (see table 1), when the number of CPUs increases from 8 to 32, the efficiency E is still high (>0.9), and when it increases to 64, the efficiency decreases greatly, see fig. 2.

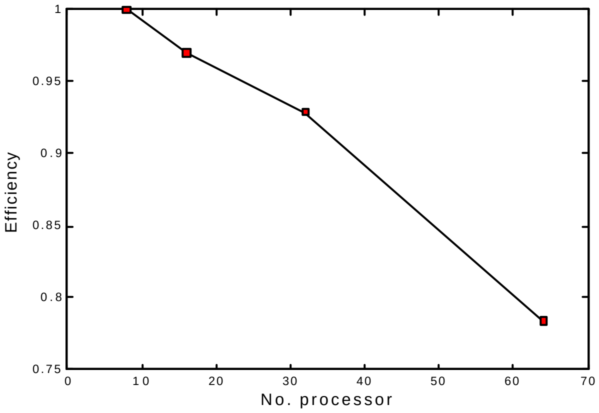

Fig. 2 Efficiency graph

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