SAR DATA PROCESSING

USING A SUPERCOMPUTER

by

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ABSTRACT

The authors have developed a software for processing the SEASAT SAR data using a supercomputer. The supercomputers, FACOM VP-200/VP-100, are vector processors with maximum performance rate of 533 MFLOPS/267 MFLOPS and large main memory of up to 256 MB/128 MB, respectively.

The software is designed to get the highest performance system. In order to reduce the CPU time, an isogeometric FFT is employed because this algorithm is suitable for a vector processor. The corner turning is not performed because 2-dimensional data reside on main memory. In order to shorten the I/O time, the parallel file access method is applied, which is a function of the FORTRAN77 /VP.

A SEASAT SAR image (90km in azimuth x 100km in range) has been processed in 20.18 minutes using a loosely coupled system of FACOM VP-200 and FACOM M-380, where FACOM M-380 is a general purpose computer. In the case that many scenes are continuously processed, the processing time per scene becomes 8.55 minutes.

1. INTRODUCTION

There are two ways to process SAR data. One is an optical processing and the other is a digital processing. From now on, a digital processing will be used mainly because it can produce more precise images and it can be easily adapted to various parameters of spaceborne and airborne SAR.

In order to process SAR data digitally, a minicomputer with an array-processor (e.g. AP120B) is used in some laboratories. Though this combination provides a high cost-performance system, the processing speed is low. For example, it takes 2 to 3 hours to process a full scene using a minicomputer with three array-processors. The Japanese ERS-1 project is planned to take 50-80 scenes per day. In order to process these data within a day, a scene must be processed within 10 minutes.

The authors have conducted a study on data processing using a super-computer since 1982.[1][2] In this paper, hardware and software features are described. In section 2, FACOM VP-200/VP-100 is introduced. In section 3, the algorithms which shorten the throughput time are described. In section 4, a example of SEASAT SAR image which was reconstructed using FACOM VP-200 is introduced.

2. HARDWARE

In order to process SAR data, two processors are used. One is a super-computer, FACOM VP-200, and the other is a general purpose computer, FACOM M-380. The hardware configuration is shown in Fig.1. These processors are loosely coupled through the shared disks. The processing load is shared between these processors. FACOM M-380 (FEP : Front End Processor) , which has 16 MB main memory, performs scalar operations and FACOM VP-200 (BEP : Back End Processor) , which has 64 MB main memory, performs vector operations mainly. The disks are shared by two processors and the volume per disk is 1.7 GB. Two magnetic tape units are used to input SAR raw data and output SAR image data. The density of these units is 6250/1600 BPI.

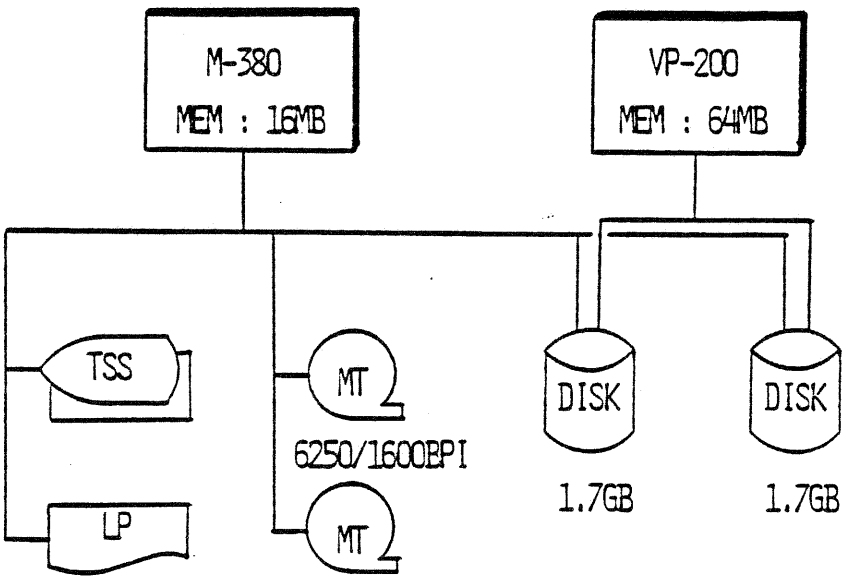


FIG. 1 HARDWARE CONFIGURATION

(4) (5)
FACOM VP-200/VP-100 is the vector processor with maximum performance rate of 533 MFLOPS/267 MFLOPS and large main memory of up to 256 MB/128 MB, respectively. The block diagram of VP-200/VP-100 is shown in Fig.2.

The vector processor consists of the scalar unit, the vector unit and the main memory unit. The scalar unit is equipped with 16 general purpose registers (GPR) , 8 floating point registers (FLPR) and 64 KB of cache memory. The vector unit mainly consists of vector registers, mask registers and six functional pipeline units, such as an add/logical pipe, a multiply pipe, a divide pipe, a mask pipe and two load/store pipes. The first three pipes perform arithmetic operations and the mask pipe performs logical operations associated with the mask vectors.

Many kinds of concurrent operations can be processed in the vector processor. In the vector unit five functional pipelines can operate concurrently ; two out of three arithmetic pipeline units, two load/store pipes and a mask pipe. Within each arithmetic pipeline unit, vector operands associated with consecutive instructions can flow continuously. The vector unit and the scalar unit can also operate concurrently.

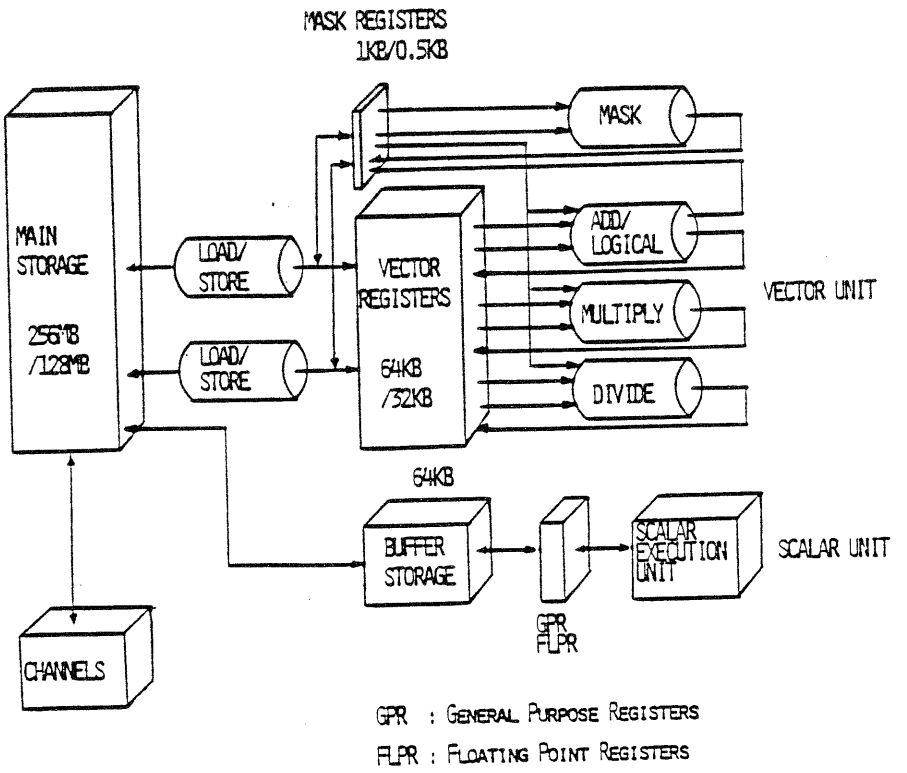


FIG. 2 FACOM VECTOR PROCESSOR BLOCK DIAGRAM (VP-200 / VP-100)

3. SOFTWARE

The software for processing SAR data consists of three steps. The first and the third steps are performed by FACOM M-380 (FEP) and the second step is performed by FACOM VP-200 (BEP) . The process flow is shown in Fig.3.

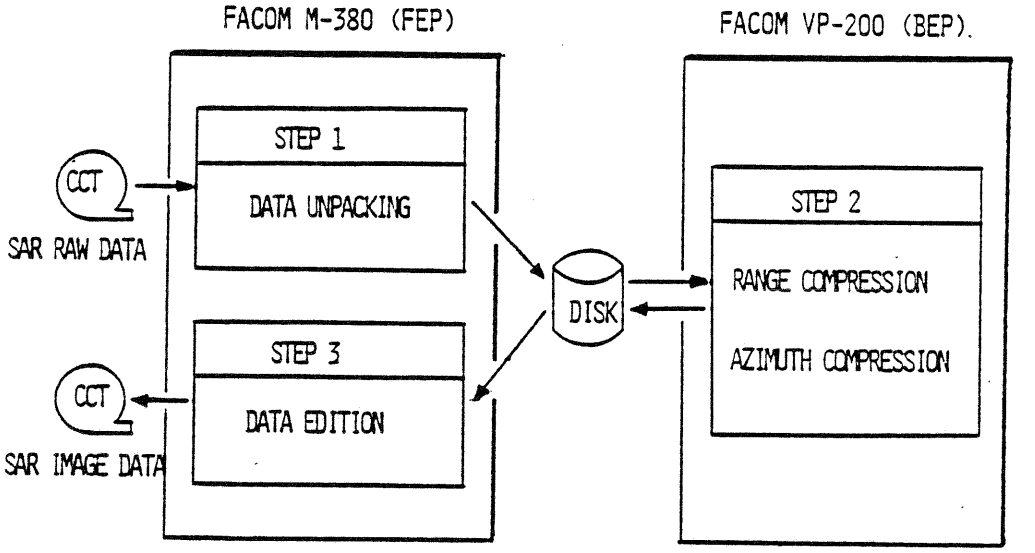


FIG. 3 PROCESS FLOW

STEP 1

This step is performed by FEP. SAR raw data is read from CCT and is unpacked to word data. The scene size to be processed is input and the image center time is calculated. The parameters necessary for azimuth compression are calculated and stored in the shared disks.

STEP 2

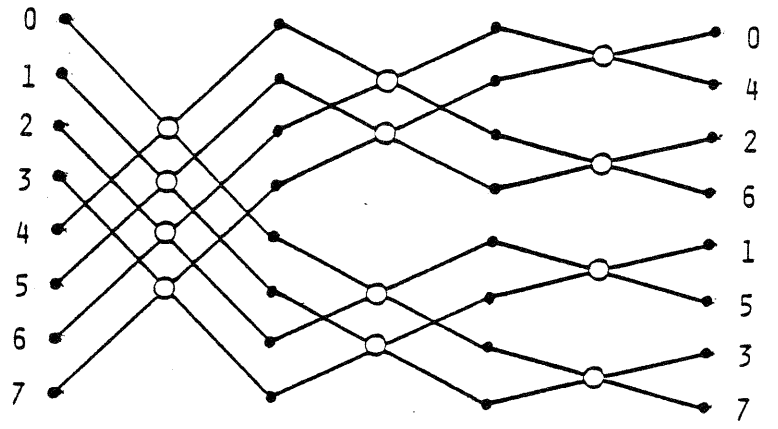
This step is performed by BEP. The subscene data (15km in azimuth x 20km in range) is read from the shared disks. The range and azimuth compression are performed in frequency domain. After the azimuth compression the data is divided into 4 looks. This 4 looks data is summed to the 4 looks data of the neighbor subscene. The corner turning is not performed because 2-dimensional data reside on main memory.

STEP 3

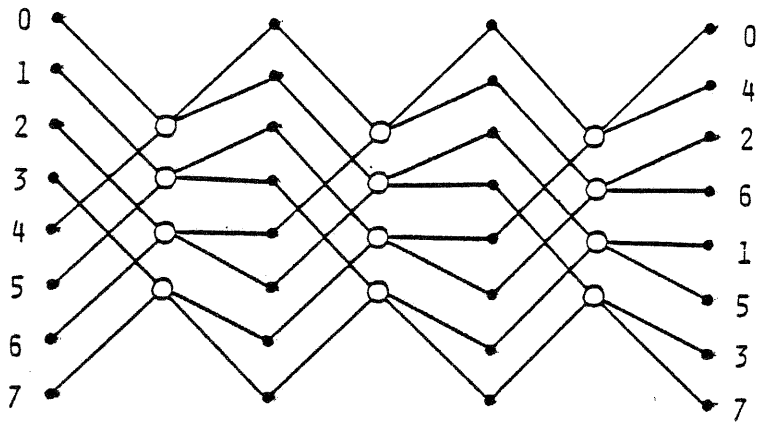
This step is performed by FEP. The subscene images, which are processed in STEP2, are combined into the scene.

The software is written in FORTRAN77 which allows automatical vectorization by the FORTRAN77/VP. Though the high speed processing is expected by this vector compiler, the algorithmic consideration is important to extract higher performance of VP-200.[3]

The largest portion of SAR data processing time is consumed by FFT, which is often used to evaluate the performance of supercomputers. There are some algorithms for implementing FFT and Fig.4 shows two of them.[6] Though the in-place FFT algorithm does not require temporary storages, its transfer pattern is considerably complicated. Since the vector length decreases by each stage, it is difficult to get a high enough performance by vector processing. This algorithm is appropriate for scalar machines with small main storage. On the other hand, though the isogeometric FFT algorithm requires temporary storages, the vector length is retained constant because its transfer pattern is fixed over all stages. So, it is easy to extract a very high performance of a vector computer. The isogeometric FFT is employed in the SAR data processing. It takes 213 microseconds to perform binary-radix, 1024 point complex FFT using FACOM VP-200.



(A) IN PLACE FFT



(B) ISOGEOMETRIC FFT

FIG. 4 COMPARISON OF FFT ALGORITHM

The corner turning is an I/O-bottleneck procedure which prevents shortening the throughput time of SAR data processing. Since general purpose computers and minicomputers have small main memory, intermediate data are stored temporally in disks. On the other hand, FACOM VP-200 has large main memory up to 256MB. In order to utilize this feature, this software uses 64MB main memory to lay 2-dimensional data (2048 samples in range x 4096 samples in azimuth) and the I/O time of the corner turning disappears.

There still remains I/O procedure between the shared disks and FEP, BEP. In order to shorten this I/O time FORTRAN77 and FORTRAN77/VP provide the high speed I/O processing. This function is illustrated in Fig.5. In this case the array data on the main memory is transferred to three disks concurrently without I/O buffers. The parallel file access method divides automatically the array data according to the number of allocated disks. In our case, two disks are used to process SAR data. So, the I/O speed becomes twice as fast as the I/O speed in the case that only one disk is used.

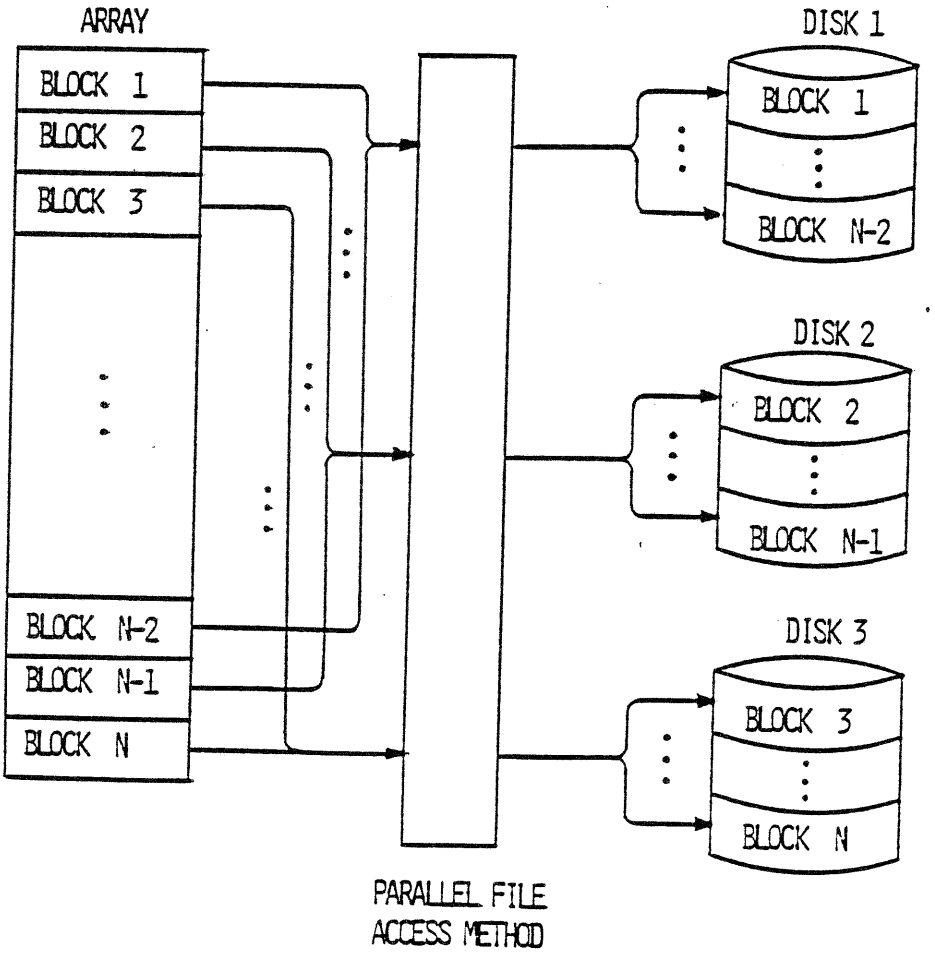


FIG. 5 HIGH SPEED I/O PROCESSING

4. RESULTS

SEASAT SAR data of Barcelona in Spain (90km in azimuth x 100km in range) was processed by the system shown in Fig.1. The image is also shown in Fig.6. The processing time is summarized in Table 1. STEP1 was performed in 9.86 minutes by FEP. STEP2 was performed in 8.55 minutes by BEP. STEP3 was performed in 1.77 minutes by FEP. It took 20.18 minutes to reconstruct SAR image from SAR raw data.

TABLE 1 PROCESSING TIME (90km x 100km SCENE)

	CPU TIME	I /O TIME	THROUGHPUT TIME
STEP 1	4.19 MIN	5.67 MIN	9.86 MIN
STEP 2	5.66 MIN	2.89 MIN	8.55 MIN
STEP 3	0.07 MIN	1.70 MIN	1.77 MIN
TOTAL	9.92 MIN	10.26 MIN	20.18 MIN
THROUGHPUT TIME PER SCENE			8.55 MIN

In the case that many scenes are processed consecutively, 3 steps are performed in parallel according to the time chart shown in Table 2. Namely, while STEP1 of the first scene is performed, STEP1 of the second scene is performed. After STEP1 of the first scene is processed, STEP2 of the first scene is performed. Like this way STEP1 and STEP3 of two scenes are performed in parallel and STEP2 is performed consecutively. By processing many scenes consecutively, a scene can be processed in 8.55 minutes.

TABLE 2 TIME CHART FOR PROCESSING MANY SCENES

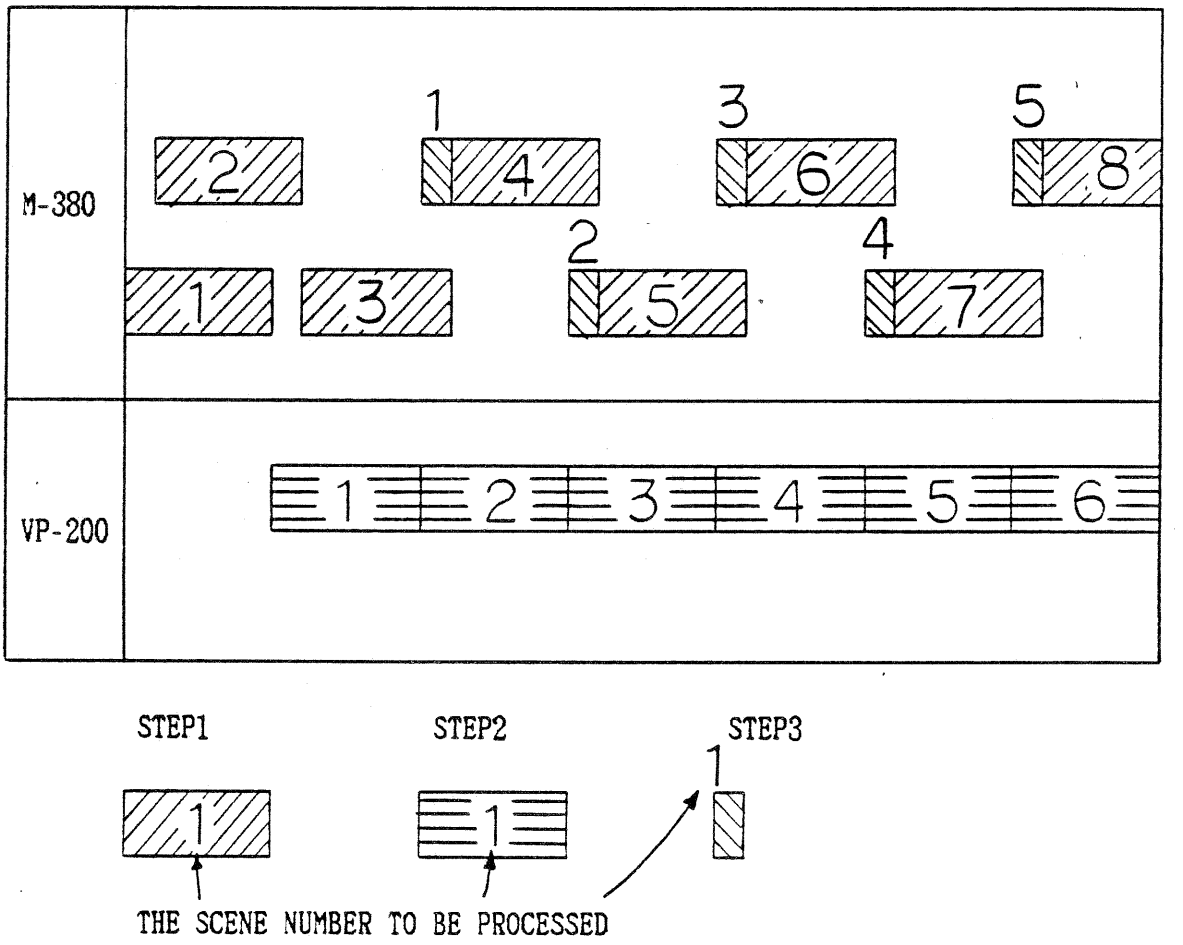


FIG.6 SEASAT SAR image of Barcelona in Spain

(90km in azimuth x 100km in range)

5. CONCLUSION

The authors have developed the software suitable for a supercomputer. SEASAT SAR image (90km in azimuth x 100km in range) was processed in 20.18 minutes. In the case that many scenes are processed continuously, the throughput time per scene is 8.55 minutes. The requirement for the Japanese ERS-1 project has been achieved by this system (FACOM M-380 and FACOM VP-200) .

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