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Parallel Implementation of Features Extraction Using Morphological Filter

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Abstract

This paper describes parallelism of image data using a parallel process and developed the parallel features extraction using a morphological filter on the new generation multi-transputer's network system. This system solved the limitation of communication problem in conventional transputer networks using Inmos T9000's virtual channnel processor and Inmos C104 packet routing switch.

A morphological filter is often applied to features extraction and pre-processing in the fields of medical image processing. However, the large amount of the calculations of morphological filters have been an obstacle to the research of this method. Therefore, a fast calculation technique is necessary. In order to achieve faster calculations, parallel processing is an effective technique. The performance and efficiency of the system is examined in regard to the recognition of shapes, parallelism and network topology. The processing software was implemented in "occam2".

Experimental results show high performance and efficiency in parallelism. Massively parallel processing systems could be implemented using this system in the future.

1 Introduction

Mathematical morphology is the theory of image and signal transformation. A morphological filter is often applied to noise reduction, edge detection, and features extraction in the field of medical image processing [1]. However, the large amount of the calculations of morphological filters have been an obstacle to the research of this method. Therefore, a fast calculation technique is necessary. In order to achieve faster calculations, parallel processing is an effective technique. A multi-processing system of MIMD is especially effective for image processing systems. In the past, the first generation transputer Inmos T805 was used for image processing systems in the case of adapted network topology, including message routing process each processors. But there were the limitations of communication in complex network system [2].

We studied parallelism of image data using a parallel process and developed the parallel features extraction using a morphological filter on a new generation multi-transputer's network. The performance and efficiency of the system is examined in regard to the recognition of shapes, parallelism, and network topology. The experimental results are reported.

2 Mathematical Morphology

Recently, mathematical morphology has been of increasing interest in the area of non-linear image processing [3]. Morphological filter are an important kind of non-linear filters which gives excellent results in areas such as pre-processing and object recognition. The method called morphological filtering on application fields consists of operations based on set theory. The four fundamental kinds of operations are dilation, erosion, opening, and closing. The definition of gray-scale morphological operations are as follows:

Suppose that a set A in the Euclidean N-space (E^N) is given. Let F and K be $\{x \in E^{n-1} \mid$ for some $y \in E, (x,y) \in A\}$, and let the domains of the gray-scale image be f and the gray-scale structuring element be k, respectively. The gray-scale dilation of f by k, which is denoted by $f \oplus k$, is defined as

$$(f \oplus k)(x,y) = max\{f(x-m, y-n) + k(m,n)\} \quad (1)$$

for all $(m,n) \in K$ and $(x-m, y-n) \in F$. Dilation causes an expansion of an image and tends to fill in small background areas such as holes or gaps. The gray-scale erosion of f by k, which is denoted by $f \ominus k$, is defined as

$$(f \ominus k)(x,y) = min\{f(x+m, y+n) - k(m,n)\} \quad (2)$$

for all $(m,n) \in K$ and $(x+m, y+n) \in F$. Erosion causes a shrinking of an image and tends to elimi-

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nate small structures such as shape peaks of narrow bridges. When combined in sequence erosion and dilation give the actions of opening and closing, respectively. The gray-scale opening of f by k,which is denoted $f \circ k$, is defined as

$$f \circ k(x,y) = \{f(x,y) \ominus k(x,y)\} \oplus k(x,y) \quad (3)$$

Opening can reduce noise from image data. The gray scale closing of f by k, which is denoted $f \bullet k$, is defined as

$$f \bullet k(x,y) = \{f(x,y) \oplus k(x,y)\} \ominus k(x,y) \quad (4)$$

Closing can fill small holes.

A applicational operation tophat $T(x,y)$ is defined as

$$T(x,y) = f(x,y) - \{f(x,y) \circ k(x,y)\} \quad (5)$$

Tophat is an edge emphasis filter subtracting the opening image using the hemisphere filter from the original image. Quoit filter $q(x,y)$ is defined as

$$q(x,y) = f(x,y) \oplus d(x,y) - f(x,y) \oplus r(x,y) \quad (6)$$

$d(x,y)$ is disk filter and $r(x,y)$ is ring filter. Quoit filter is for classification of isolated peaks. Quoit filter can detect circumscribed shadows like typical cancer regions. This is accomplished by subtracting dilation image data using a disk-filter from dilation image data using a ring-filter.

3 Parallel Processing Method

The conventional approach has been to increase the speed of sequential processors by the use of higher clock-rate, higher component density, and faster technology. Still, there were limitations of the performance.

In order to achieve high performance of image processing, parallel processing is an effective technique. Image processing allows data to be distributed across the network and for each processor to act on a subset of that data. An image processing task which is divided among N-processors and can run in 1/N-th is addressed theoretically.

The processors depend on each other and are either waiting for a transfer of data or spending time passing message among themselves. The first generation transputer Inmos T800 is designed to make possible the implementation of scalable parallel processing systems. In the past a programmer could only assign one channel, one in each direction for each link.

Now, the new generation transputer Inmos T9000 is designed to provide for higher performance and greatly improved communication facilities. The T9000 is capable of average performance 80MIPS and 10Mflops. The T9000's four communication serial links provide a 100Mbps. The T9000 solved the limitation of communication problem using a virtual channnel processor and Inmos C104 packet routing switch. The solution chosen in the T9000 was to add multiplexing hardware to allow any number of processes to use each link. The pysical links can be easily shared. The C104 allows simple fast communication between T9000 transputers that are not directly connected. The C104 can communicate at 100Mbps

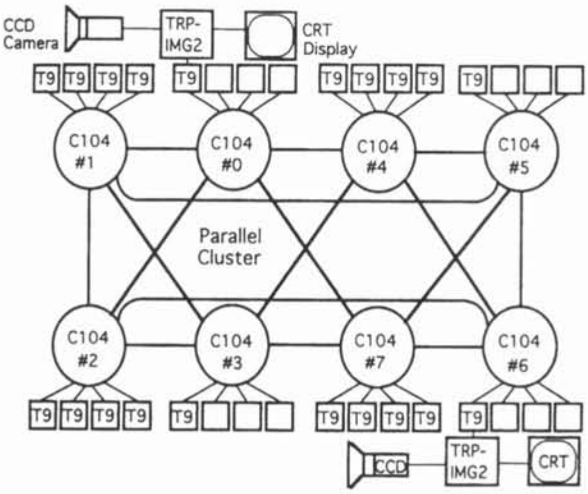

Fig.1 Hardware Configuration of Experimental System.

each other T9000 or C104. Transputer can form a network that is easily scalable and configurable. Such features are implemented by a CSL Parallel Cluster. A Parallel Cluster can include eight C104s and thirty-two T9000s which can connect flexibly among themselves.

4 Experimental Methods

For the purpose of the system evaluation, we configued parallel image processing system as shown in Fig.1. A Parallel Cluster allows for great flexibility of the network topology, and is user-friendly. An image data is divided horizontally to apply geometric parallelism. At the first, We developed six morphological operations using a single T9000. The flow of single image processing are as follows:

(1) Acquired image data by CCD camera, having a size of 512×480 pixels, were processed on a TRP-IMG2 board which included three Inmos A110 DSPs.

(2) Image data was transfered to root T9000, and one of the morphological operation was carried out.

(3) The processed image data was transfered to a TRP-IMG2 board, then displayed on a monitor. Processing time was displayed at the host computer. Next, We developed the programs of parallel image processing using from two to twenty T9000s. The flow of parallel image processing are as follows:

(1) Acquired image data by CCD camera was processed on a TRP-IMG2 board.

(2) Image data was divided horizontally and transfered concurrently each T9000 according to number of parallel processing images.

(3) Then each of T9000s received concurrently image data, which merely carried out one of the morphological operation a distributed area.

(4) The processed image data was simultaneously transfered to a TRP-IMG2 board. The image data was composed and display on the monitor. The pro-

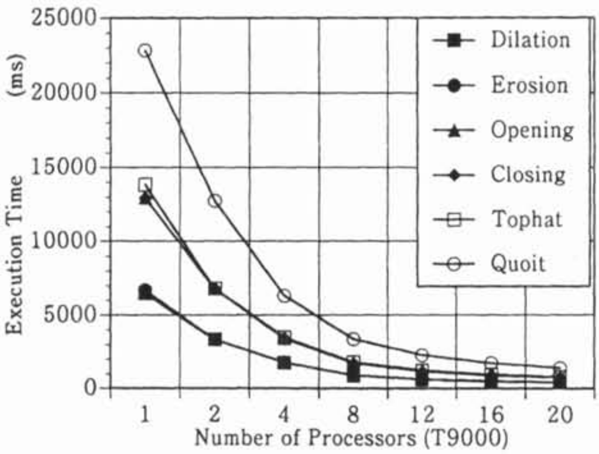

Fig. 2 Execution Time (3 × 3 filter)

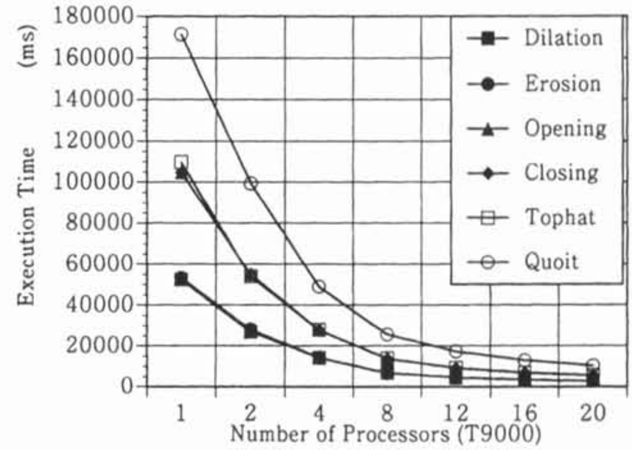

Fig. 4 Execution Time (9 × 9 filter)

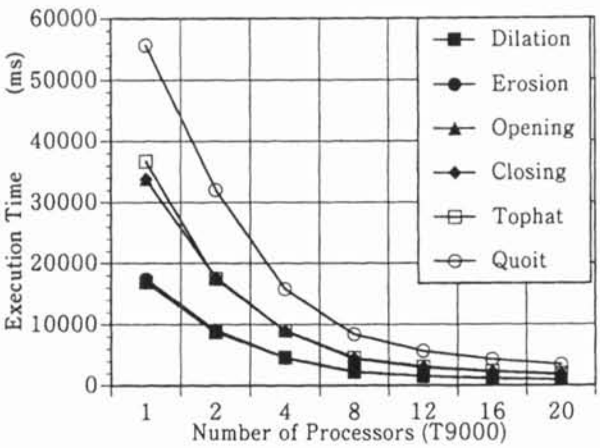

Fig. 3 Execution Time (5 × 5 filter)

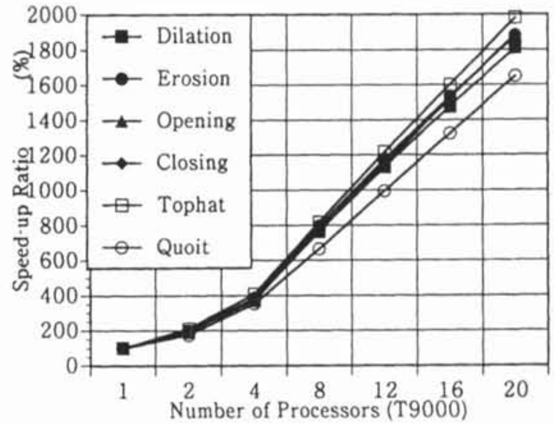

Fig. 5 Speed-up Ratio (5 × 5 filter)

cessing time and communication time were displayed at the host computer.

All program were implemented in "occam2". Occam2 is highly suitable language to develop parallel processing system utilizing transputers.

5 Experimental Results and Discussions

Using the above experimental system and the developed the programs of morphological operations, performance measurements are the follows. There are four kinds of experimental results about parallelism and one photograph of applicational morphological operation.

(1)At first, experimental results of execution time were shown in Fig.2, Fig.3, and Fig.4 varying the parameters about the number of processors and the size of filters. In spite of the inclusion of the communication time of image data at multiprocessing, the execution time was decreased linearly according to the number of processors. The virtual channel processor seemed to function very well.

(2)A speed-up ratio is an important performance of parallel processing system. A speed-up ratio is defined as the execution time of single processor divided by the execution time of parallel processors, and multiplied by 100(%). A speed-up ratio using 5×5 filter as shown in Fig.5 indicates opening operation. Sufficient results were obtained using twenty processors at 1887(%).

(3) The measurement of efficiency was very important for the effective use of parallel processing system. The efficiency of parallel processing system is defined by the execution time of a single processor divided by the execution time of a multiple processors, and multiplied by the number of used processors. The efficiency using 5×5 filter was shown in Fig.6. The efficiency of opening operation was excellent, about 94.3(%) at twenty processors. The results show high performance and efficiency in parallelism. Otherwise, the super-linear phenomenon resulted at tophat operation. Super-linear rarely caused by which instructions were able to include cache memory on T9000 and the total communication time was small.

(4)T9000 communicates by bi-directional serial link about 100Mbps, using a virtual channel processor. The communication time of image data is according to number of parallel processors as shown in Fig.7. In order to increase the number of processors, the communication times were decreased. For example, the reduction was approximately $7(ms)$ using twenty processors. The performance of commu-

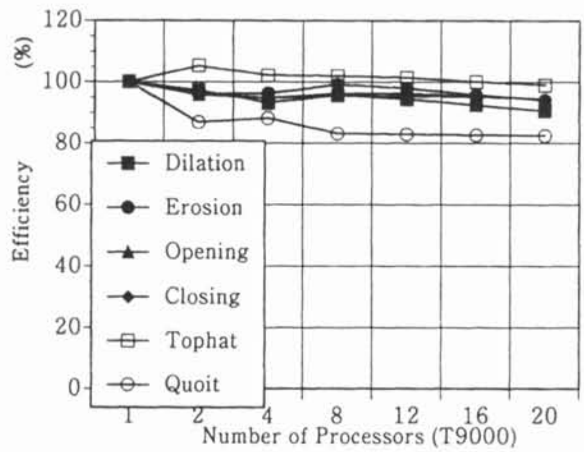

Fig. 6 Efficiency of Processor (5×5 filter)

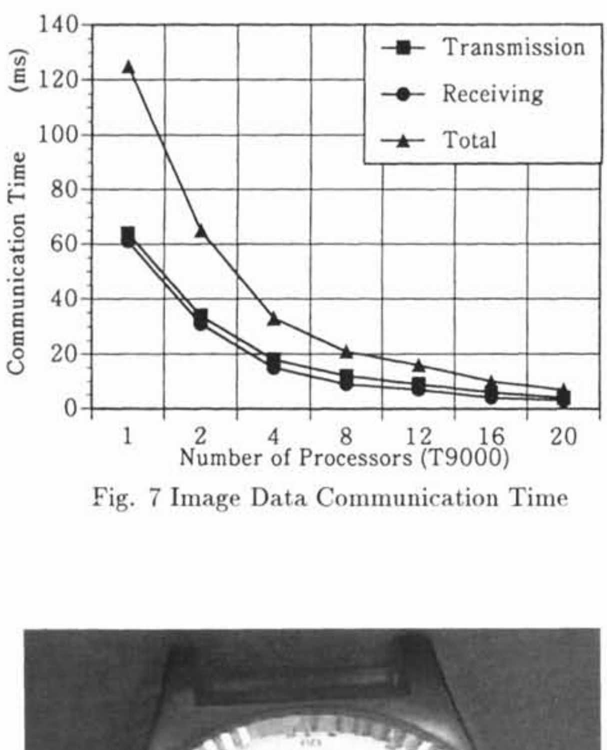

Fig. 7 Image Data Communication Time

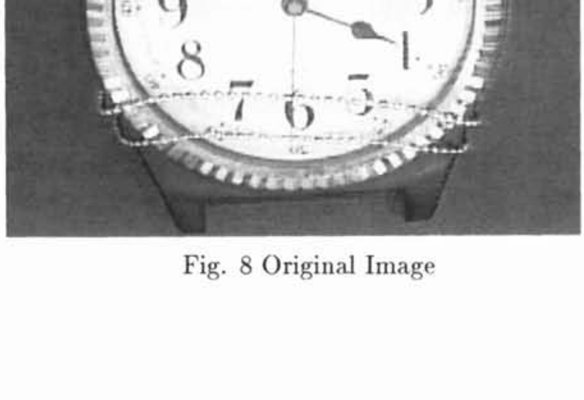
Fig. 8 Original Image

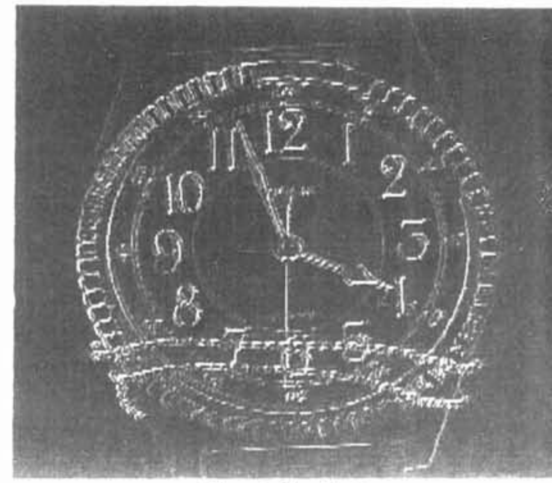
Fig. 9 Quoit Image

nication speed was excellent results. In this experiment, we did not use group adaptive function, so we can expect higher performance in the future.

(5)The results of morphological operation is shown as follows: original image is shown in Fig.8. Fig.9 shows a quoit operation using a 9×9 disk-filter and 3×3 ring-filter. The edge of the image is completely extracted.

6 Conclusion

We studied parallelism of features extraction using morphological filters on a new generation of multi-transputer's network. The performance and efficiency of the new transputer system is examined in regard to the recognition of shapes, parallelism, and network topology. Experimental results is shown high performace and efficiency in parallelism. As a result of these experiments, massively parallel processing systems could be implemented in the future. This method will be further advanced through improved studies on structuring elements, parallel algorithms, and network topology.

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