Use of Transputers for the Fast Determination of Shapes Corresponding to Blood Vessel Network via CCD - IR Images

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Abstract In this work the use of a transputer network as a parallel processing device for medical shape analysis is examined. Our hardware platform consists a SUN SPARC 2 workstation acting as the host processor, connected via it's SBus to the master transputer of a lattice network containing 32 T800 transputers acting as workers. IR filtered images of a CCD camera system connected to the network are used as the basis of the investigation. Objects corresponding to blood vessels of the human body are determined through fast parallel boundary detection, scan conversion filling, thinning methods and shading algorithms. A significant speedup could be achieved by the developed method and it can be applied for larger images without size limitation.

1. *Introduction* It is never a simple task to determine objects and shapes within images especially when the time requirements for this operation are severe. Object detection tasks are often facilitated by binarization of the input images such that the resulting homogenous regions define the shapes in question. Several qualitative and quantitative techniques have been developed for this purpose. These methods are usually slow, because large number of computation are requested to carry out neighborhood operations on large image data . In order to achieve a quick software and hardware system for the solution of this problem it is unavoidable to use parallel computing.

In this work the use of a transputer network as the basis of the parallel image analyzer system for determining objects corresponding to blood vessels is investigated. IR filtered images of a CCD camera system connected directly to the transputer network are applied as the input of the system. We propose a parallel second derivative boundary detection based object determination technique for the extraction of medical objects. Both algorithmic and data flow parallelization are applied in order to obtain an effective parallel technique and implementing it on the actual transputer network.

2. *The IR Image Analyzer Hardware* As the image source, we use a camera device consisted of two infrared (λ=200-400nm), one visible (λ=400-700nm) and two ultraviolet CCD cameras (λ=700-1000nm), their iris and focus controlling boards and motors. The image to be taken is divided by the mirrors working as filters in order to get the proper wavelength interval for each camera. Analog video signals are taken from this device and fed into the transputer box, which contains not only the network and main boards but the A/D converter system as well. An 8 bit, 20 Msampling/s analog digital convertor is applied for each CCD video signals and 8 bit digital/analog convertor for the focus, iris and zooming on each CCD camera controller. Our parallel computing network is based on 32 T800 transputers. The transputer is one of the simplest and most suitable unit to build up cheep parallel processing systems, and the T800 is the fastest type of them, that is available now. It is essentially a computer on a chip: a 1.5 Mflops RISC processor, complete with memory, data links, and system services. As each transputer has four data links with 10-20 Mbit speed, various kinds of topology can be built upon their base. In our case two 4x4 lattice grid connected to each other as a pipeline are chosen, which was found as the most suitable and cost effective for computation problem on the image array. The digitized image coming from the A/D converter board is stored on the video memory that is mapped on the main transputers extended memory space. The LUTs used for the displaying of the various types of original images and their linear combination are located on the main memory as well as that two bytes called in and out. The first one (in) is used for scheduling the input data sampling, while the second one (out) is used as a switch for the selection of the required LUT or VRAM area. The memory area used for the camera selection of the focus and iris control are located on the camera device and supervised by data strobes. The calculated image that is contemporary stored on the main memory is sent to the root transputer via RS422 interface. The root processor is also a T800 transputer located in the Sun SPARC station 2 used as the host machines connected via SBus into the host system. In our case the host machine's function is not only to perform the user interface but the displaying and further improvement of the calculated image data. (The diagram of system is shown in Fig. 1..)

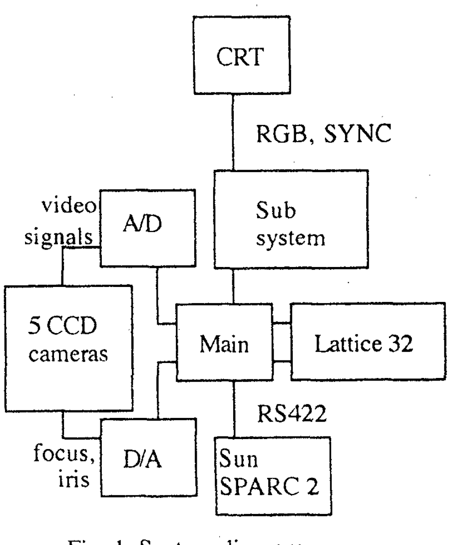

Fig. 1. System diagram

3. *The parallel image analyzer software* As a first step of the processing, objects are determined by extracting features based on edges located on object boundaries. For detecting the contour point candidates a second derivative edge extracting algorithm is applied and parallelized on the basis of the decomposition of LoG operation into two independent horizontal and vertical calculation [1,3]. The functional form of the Laplacian of Gaussian (LoG) operator:

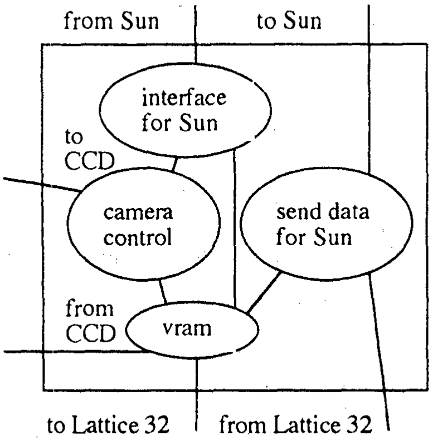

Fig. 2. main transputer softwear structure

$$\nabla^2 G(x,y) = f\left(2-\frac{(x^2+y^2)}{\sigma^2}\right)\exp\left[-\frac{(x^2+y^2)}{2\sigma^2}\right] \quad (1)$$

where f is a scale factor. Equation(1) can be rewritten as the sum of two separable filters, $g_{12}(x,y)$ and $g_{21}(x,y)$ as follows:

$$\nabla^2 G(x,y) = g_{12}(x,y) + g_{21}(x,y) \quad (2)$$

where

$$g_{12} = g_1(x)g_2(y) \quad (3) \qquad g_{21} = g_2(x)g_1(y) \quad (4)$$

$$g_1(\upsilon) = \sqrt{f}\left(1-\frac{\upsilon^2}{\sigma^2}\right)\exp\left[\frac{-\upsilon^2}{2\sigma^2}\right] \quad (5) \qquad g_2(\upsilon) = \sqrt{f}\exp\left[\frac{-\upsilon^2}{2\sigma^2}\right] \quad (6)$$

The parallel method based on this decomposition is implemented by algorithmic and data parallelization as well. First we distribute the image into smaller overlapped segments according to the number of nodes and load the image data into the network. The tasks of the calculation on the segments of the image data are assigned to the transputers of the network. The one-dimensional convolution steps are accomplished parallel on the segments of the distributed image space. In this method redundant data are stored in each transputer that is not necessary to be communicated. This approach avoids the problem of the communication overhead but it needs a big memory space on the nodes extended memory to store the data of the overlapping segments. This data parallelism provides a significant flexibility and scalability in the network, but this method requires a great amount of data storage if the amount of data increases. The boundary detection could be carried out less then 7s on the 32 nodes by this method for 512x512 size images compared to the 5 minutes was spent on a single 28 MIPS Sun SPARC station. In order to avoid the danger of deadlocks communication control tasks are carried out on each node. The boundary located by zero crossing points is locally refined in subpixel accuracy in order to obtain smooth close curves or curves that terminate at the boundary of the image.

For the further rendering of the detected shapes a recursive scan conversion filling technique is accomplished[4]. Interior points of boundaries are obtained and independent tasks are assigned to the transputers carrying out a traversal starting from these points on a segment of the image space located to each node. Any time when the traversal being carried out on a processor is out of the local image topology the location data is sent via communication processes. New starting points are stacked by the determination of the degrees of nodes of the line adjacency graph corresponding to the boundary point have been reached. Thinning is performed to represent the abstract structure of the objects for topological analysis and classification in order to determine the accurate blood vessel network map of the given body area[2]. In this procedure the checking of the skeleton point conditions in an image segment can be accomplished parallel on a group of transputer by an appropriate synchronization of performing a set of pattern matching operations.

As a programming language we used occam for implementing the algorithms on the transputer network. This high level language contains all of the data structures that are necessary for writing parallel applications [5]. However using C language would have been fit better to the host side programming and communication -the user interface and the displaying are written in C on the host machine - we chose occam, because it generated a smaller and more effective code and the programming design and debugging became easier. (Fig. 2. shows the program structure on the main transputer.)

For providing a 3D illusion shading is applied for this approximation. The shaded color of each point is represented by the sum of the reflected, scattered, absorbed and transmitted light by applying interpolative shading[6] on the basis of the intensity values. A smooth, realistic picture could be achieved on this basis.

4. *Conclusions* Through actual implementation on images of the human body, a global ten times speedup could be reached by the 32 nodes compared to the performance on the single Sun SPARC station 2. The developed parallel method could be easily applied for larger images and different kind of pictures. Applying the method for larger images, the speedup decreased because of the increasing data amount had to be stored and communicated between the nodes, but still remained significant. We found the transputer network very suitable for object analysis tasks due to not only it's high performance but flexibility as well.

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