The Use of the Multiprocessor Systems For the Reconstruction And Visualization of 3D Objects

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Abstract

This work deals with the application of multiprocessor systems for the reconstruction of 3D objects from 2D layer representations of object and the 3D visualization. The signal processor TMS320C40 is offered to be used as the base element. The features of architecture and software of the multiprocessor system are considered, the estimations of performance in different configurations are given.

1. Introduction

One of the fast developing areas in the field of the computer techniques at present is the 3D computer graphics. The successes in the development of the hardware and software results in great number of new applications - CADs, image recognition systems, medicine, art, advertising, virtual reality and others. At the same time, the quality requirements for the 3D images are increased. For the best perception, they should have all properties of the real images of the environmental world - the high resolution, number of details, shading, complex textures, reflections, atmospheric effects. As a result the amount of calculations of 3D graphics is sharply increased. Some applications also require the calculations in the real time, for example, for reception of the images of the driven objects. All this requires a very powerful hardware resources. By estimations the computing systems performance for problems of a virtual reality should be 2 GFLOPS, and for image recognition in the sequences of the images - 4 GFLOPS [1].

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There are a few applications, in which the initial information for creation of the 3D scene is the 2D image of object layers, from which it is possible to allocate the information on the internal structure or the external contour of object. The X - ray and NMR tomography, the research of the microobjects by the microscope, the reconstruction of the 3D objects on the geographical contour maps are some examples of the applications. As a general rule these applications are critical to the speed of processing of the quality 3D images. In some cases the calculation of the dynamic images in real time is required.

At present, none of the existing microprocessors has performance necessary for the creation of the quality 3D images in acceptable time. One of the ways of increasing the performance of the computing system is 3D graphics accelerators, i.e. additional processors, at a hardware level carrying out some operations of the 3D graphics. As the problems of the calculation of the 3D image has internal parallelism, the other way is the construction of multiprocessor systems, consisting of identical processors, connected with each other in a special way, working in parallel and carrying out the part of a general problem. The advantage of such systems are: an opportunity of increasing the general performance by simple addition of new elements and some flexibility, by which the same system is possible to be used for the different problems meeting the parallelism inherent in a problem.

In the given article, the features of the construction of the multiprocessor systems for the reconstruction of the 3D objects from the 2D layers images and their visualization are considered. In chapter 2, the features of the algorithms are shown, and the possible schemes of construction of the computing system are given. In chapter 3, the opportunity of the use of the signal processors TMS320C40 as processor elements is considered. In chapter 4 the approaches for an experimental estimation of performance of the offered computing system are shown.

2. Methods of construction of multiprocessor system

The algorithms of reconstruction of the 3D scene from the 2D images of layers can be divided as follows:

- Preparation of model. At this stage, it is necessary to allocate the contours of objects in each of layers, finding the essential points of these contours, and then constructing a surface skeleton on these points between the two next layers by realization of the procedure of approximation in some way [2].

- Visualization of constructed objects. At this stage standard methods and algorithms of the 3D computer graphics is used - geometrical transformations, shading and others.

The application of multiprocessor systems gives the good results for computing algorithms, which have internal parallelism and guarantee the minimum information interchange between the processors.

At the first stage - the preparation of model - the use of the parallel processing of layers is offered (fig.1).

In processors à1, à2 and à3 the information of the appropriate layer is placed. After this each of processors allocates contours of objects on its layer and finds

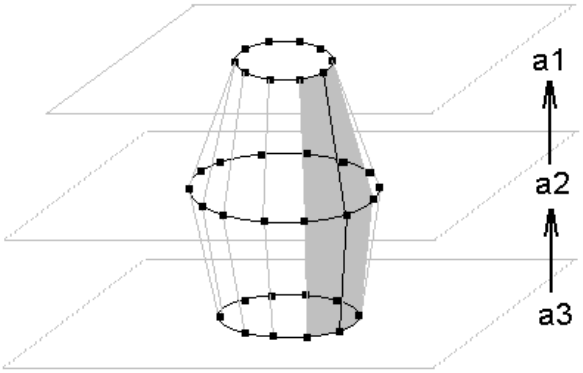

Figure 1 Scheme of the layers processing distribution

the essential points of these contours. For the construction of a surface between the next layers, the processor should have the coordinates of the essential points of these layers. It is carried out by copying of the data from à2 in à1, and from à3 in à2.

In this scheme for the maximum performance, the quantity of the processors equal to the amount of layers is required. Also the exchange between the processors will be minimum. The possible scheme of the computing system is shown in fig. 2.

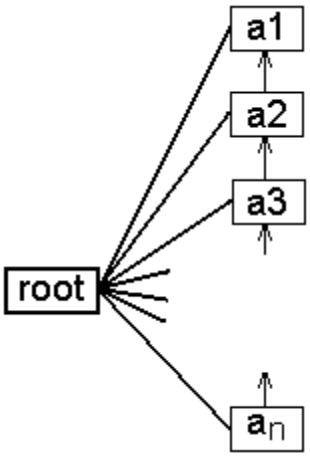

Figure 2 Scheme of the computing system for preparation of 3D objects model

Root - processor is used for data input from the outside, it distributes these data among working processors, receives the processed information from working processors, assemblies and moves out the model.

With the limited amount of the interprocessor interfaces at the processor elements, for example, 10, the computing system will consist of several levels, a, b, c and etc. (fig. 3). Thus the time of the initial information loading will increase. Delays for transfer of the processed information from level b in the root-processor will also increase, as the intermediate processors a_n can be busy.

At a stage of visualization of constructed model various algorithms of the 3D graphics are used. These algorithms give a set of several versions of parallelisms, for example:

- Method of ray tracing , at which the calculations of parameters of each visible pixel can be made irrespective of other pixels. In this case the computing system will include a few thousands processors, each of which calculates its pixel, and the time of calculation of the whole image will be equalled of time of the most complex pixel calculation.

- Parallel calculation of parameters of several polygons - coordinates, texture, shading and etc. - each on its processor.

- Pipeline calculations of parameters of the polygons

and others.

Algorithms provide small volume of the information, which the processors should exchange among themselves. Basically, this is the initial information of a calculated scene (point of vision, point of illumination, material of object and etc.), which is necessary for the start of the calculations, and the processed data of a pixel or object.

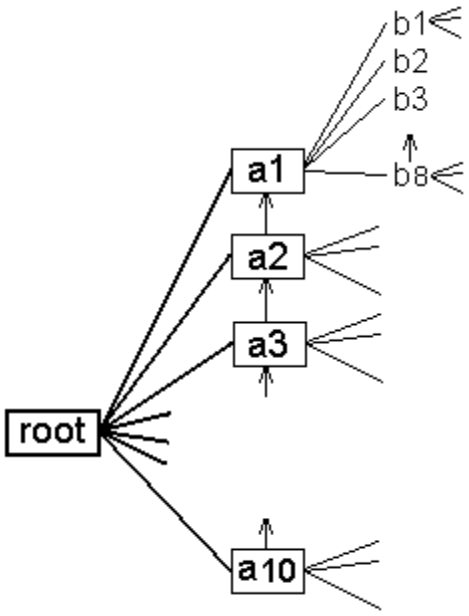

Figure 3 Scheme of the computing system on the base of the processor elements with limited amount of interprocessor interfaces

At a stage of visualization it is possible to use the scheme suggested above, i.e. run parallel calculations on each of the processors for the visualization of the 3D polygons, which forms the surface of the object between layers. It will allow to reduce the time of an interprocessor exchange as the information about the polygons is already in memory of processors (after first stage). The computed data will be transferred to the Root - processor, which carries out final formation of the image and moves it out the system.

Variety of methods and algorithms of the 3D objects visualization, which have different requirements of the computing system performance, the memory capacity, volumes of an interprocessor exchange, and different quality of the 3D image calculated by these methods, requires the creation of the universal structure of the computing system, which uses the parallelism, inherent in the different algorithms, and minimizes restrictions on the amount of processor in the system and on parameters of

real processor elements (capacity of the available processor memory, amount of interfaces for an interprocessor exchange). The example of such system is shown in fig. 4.

In this scheme the algorithm of visualization with the parallel processing of layers described above can be realized. The data of the layers are moved from lower to upper processor arranged a column (ð1-$ð_n$, p11-p_{nn} and etc.). Time of interprocessor exchanges is increased in this case, but there is no delay by the transfer of the processed information to the root-processor.

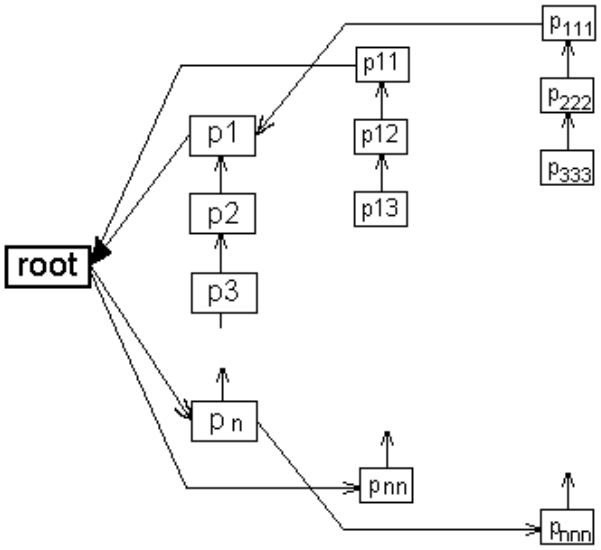

Figure 4 Scheme of the computing system applicable to various algorithms of visualization

In this scheme a pipeline principle of processing can be realized, at which the complex algorithm is broken into more simple operations. The pipeline is placed on a column of the processors, each of operations is placed on its own processor. When the quantity of the interprocessor interfaces are enough, the end processors of the pipelines can be connected. It will reduce the interprocessor exchange of initial data for upper pipelines.

For selecting that or the other scheme, it is necessary to make an estimation of used algorithms on available hardware equipment - the structure of the algotithm, running time of each operation, amount and speed of an interprocessor exchange.

Further the schemes of construction of offered computing systems on the basis of signal processors TMS320C40 will be considered.

3. The use of the processors TMS320C40

The signal processors TMS320C40 are Texas Instrument production and are intended for construction of inexpensive multiprocessor systems for various purpose.

TMS320C40 is the universal microprocessor with a wide set of instructions, has performance of 60 MFLOPS, 6 communication ports (links) with the throughput 20 Mbyte/sec for the interprocessor exchange, internal cashe-memory and 2 interfaces for the connection of external memory (8 Mbytes). All external interfaces are equipped by DMA controllers, therefore a minimum of processor time is spent for the exchange. Such characteristics allow the use of TMS320C40 as a processor element in multiprocessor systems for the different algorithms, to investigate parameters of computing systems and to find the optimum architecture and program decisions.

On the basis of TMS320C40 it is possible to construct multiprocessor systems offered earlier. One of the disadvantage of processor elements is the limited amount of interprocessor interfaces (6), therefore the computing system will consist of several levels, as shown in fig. 3.

Frequently the hardware for the parallel calculations on the basis of TMS320C40 is carried out as motherboards, on each up to 4 processors can be installed. One or several such motherboards can be installed in the PC or workstation. The exchange between the CPU of the Host-computer and motherboards can be made by one of standard interfaces (ISA, PCI) . More exactly the exchange is made between the central processor and one of processors (root) by one interprocessor link. It is possible to connect the processors located on the different motherboards in the any order (fig.5).

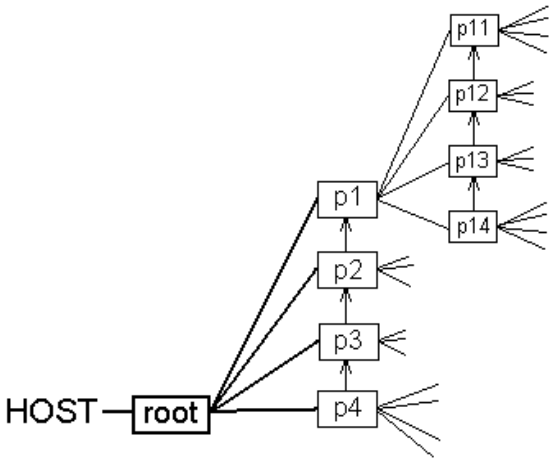

Figure 5 Scheme of the computing system on the base of the processor TMS320C40

There are also the modules, on which together with TMS320C40 the videoadapter is placed. Such modules can be used for the output of the calculated image directly on the monitor. Then there is no necessity to spend additional time for the transfer of the image data in the Host-computer. Thus, it is possible to construct a few schemes of the information interchange between the Host-computer and the network of processors (fig. 6,7,8).

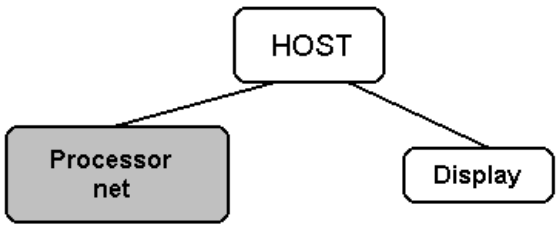

Figure 6 Scheme of the exchange between the Host-computer and network of processors

In these schemes HOST- computer carries out a few tasks: the load of a program code in the processor elements of a network, the transfer of the information about 2D layers and 3D scene in the root-processor, the receiving of the calculated image data from the network and the output on the monitor.

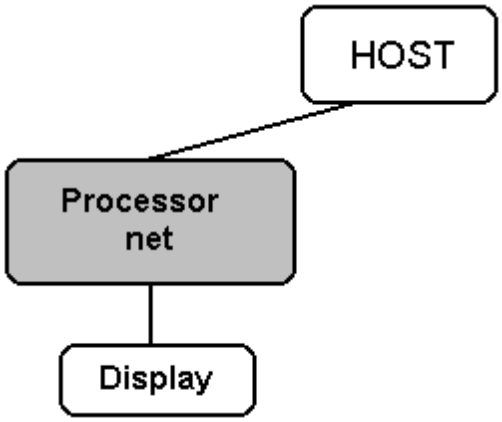

Figure 7 Scheme of the exchange between the Host-computer and network of processors with the use of the built - in network videoadapter

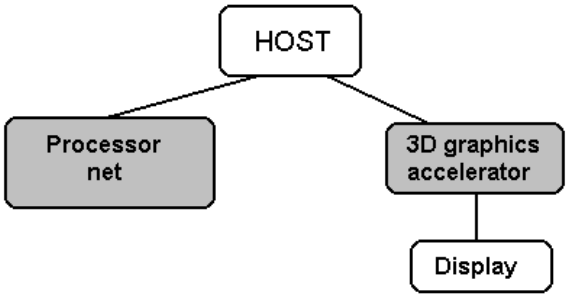

Figure 8 Scheme of the exchange between the Host-computer and network of processors with the use of the 3D graphics accelerator

The input of the information about 2D layers directly from the special external equipment in the root-processor, and also the output on the monitor directly from a network passing the HOST- computer is possible.

The scheme with the use of the standard 3D graphics accelerator has the special interest. In this case the part of calculations for the visualization of 3D objects (after the creation of the skeleton in the network of processors) can be carried out on the accelerator optimized for the visualization algorithms.

4. Performance estimations

For the performance estimation of the computing system the next algorithms are chosen:

- Constructions of the object surface skeleton between the next layers by the triangles on the set of the contour essential points.
- Geometrical transformation of the coordinates of the triangles vertex by multiplication to a matrix of the appropriate transformation.

- The triangles shading and removing of invisible lines by the method of the scanning line [3].

The schemes of computing systems used for the estimation are shown on fig. 9.

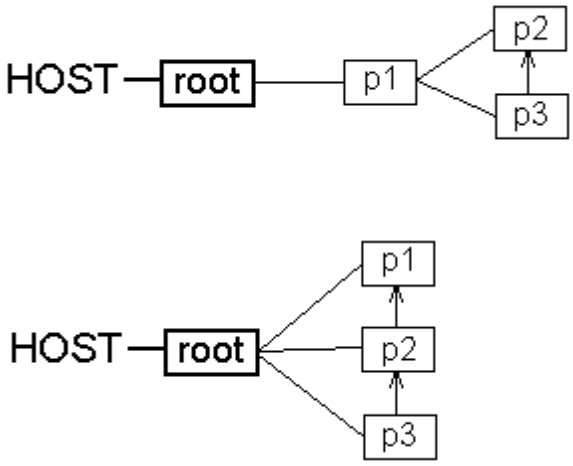

Figure 9 Scheme of computing systems used for the estimation

These schemes simulate pieces of computing systems offered above. On their basis it is possible to measure the time of the base algorithms running. With the use of the first scheme it is possible to measure the time of the exchange through the intermediate processor ð1. On the second scheme the pipeline of described above operations can be realized: the processor ð3 builds the triangles between the next layers, the processor ð2 carries out geometrical transformations of the vertex coordinates, processor ð1 carries out the shading of the triangles, the root-processor collects the image.

The experimental data will be presented in the conference report.

5. Conclusion

The features of algorithms are shown, possible schemes of construction of the inexpensive multiprocessor computing system on the basis of signal processors TMS320C40 for problems of the reconstruction of the 3D objects from the 2D layers images and their 3D visualization are given. The special attention was given to the structure of the computing system. It is universal and can effectively be used for different algorithms of reconstruction and visualization of 3D objects at a few amount of processor elements, and also can easily be increased without significant change of the software.

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