Development of an effective model of parallel processing of multimedia data on the CPU and GPU in the cloud system

V Shardakov¹, D Parfenov¹, I Bolodurina¹,², V Izvozhikova¹, V Zaporozhko¹ and A Mezhenin³

¹ Orenburg State University, ave. Pobedy 13, Orenburg, 460018, Russia
² Federal State Scientific Institution "Federal Research Centre of Biological Systems and Agro-technologies of the Russian Academy of Sciences", 29, 9 Yanvarya st., Orenburg, 460000, Russia
³ Saint Petersburg National Research University of Information Technologies, Mechanics and Optics (ITMO University), Kronverksky ave. 49, St. Petersburg, 197101, Russia

E-mail: fdot_info@mail.osu.ru

Abstract. The paper deals with the technology of paralleling processing multimedia data process on the CPU and GPU of the user's personal computer. To do this, we have developed an algorithm for planning the sharing of video accelerators, which controls and distributes the load between the processor and the GPU. The main difference of the proposed algorithm is that the integral transformations include the stabilization of three-dimensional objects and textures. Defining a unique sequence number allows you to apply optimal texture filtering when scaling for each object. These actions create optimal video acceleration when processing objects.

1. Introduction

The relevance of the study is manifested in the need for technological modernization of the system of processing of multimedia data based on the virtualization of resources in the cloud educational environment. The proposed innovative approach will solve the problem of resource optimization in the processing of multimedia data by reducing the load on the CPU, video and RAM, which will effectively distribute the computing resources of a personal computer and use 3D technology in the educational environment for training students and staff of enterprises. Possible users of the developed technology are:

- medical students will be able to acquire a virtual practical experience of interaction with patients in conditions as close as possible to the real;
- students in the design and construction areas of training will be able to see the 3D-model of the designed building, its design;
- students of natural Sciences will be able to perform virtual laboratory work using a variety of chemical compounds in a safe environment, without endangering themselves and others;
- students of technical areas will be able to study the design and details of individual components and assemblies that are part of complex and expensive systems, while the environment will allow them to interact with such systems.
The virtual educational environment in which continuous streams of multimedia data function, and 3D modeling of objects and processes of various subject areas is realized, is a fast-developing, multilevel and multifunctional system which unites:

- pedagogical, didactic and methodical technologies;
- information resources: databases and knowledge, e-learning courses;
- modern software: software products and shells.

The most popular components when working with multimedia data in a virtual educational environment are the following: CPU (Central Processing Unit) and GPU (Graphics processing unit) when rendering a three-dimensional scene. Therefore, to ensure the work of the student in a virtual educational environment is required to solve the problem of effective distribution of flows of multimedia computing resources. Currently, there are no universal solutions that can simultaneously distribute and balance the load between different computing resources of a personal computer in a multithreaded multimedia data circulating in a virtual educational environment.

To evaluate the effectiveness of existing solutions and optimize the processing of multimedia data, it is necessary to develop appropriate models and use high-tech theoretical and experimental methods of study.

The paper proposes to apply paralleling of multimedia data processing on the CPU and GPU using the modern concept of cloud applications in a virtual educational environment. To do this, it is necessary to develop an algorithm for planning the sharing of video accelerators, which controls and distributes the load between the CPU and GPU.

2. Related work

The relevance of this scientific problem is confirmed by theoretical and practical works of foreign and Russian researchers.

Russian scientists from Ufa in their work presented the architecture of the proposed model of the virtual presence system based on SDN (software-configured networks). At this stage, only the architecture of the hardware-software complex of virtual presence based on SDN technologies is proposed, but the authors did not show the development of the algorithm of the method and implementation [1].

Researchers V. N. Gridin and I. E. Bugaenko present a method of obtaining panoramic images using mathematical apparatus of fuzzy logic. This approach can be used to make multiple images with the same region, one solid panorama. This approach is optimal when working with a two-dimensional image, but not with three-dimensional models [2].

Other methods suggest using a combination of several small textures imposed on the model with multiple repetitions. In [3] it is proposed to use a linear color combination of 4 textures with weights, which are contained in the components r, g, b and a of the fifth, control, texture. This method is effective, but does not give a high realism of the image, because only 4 materials are used. In [4] describes an algorithm that combines different textures by alpha mixing depending on the height of the surface. Some other approaches suggest calculating color based on surface characteristics. For example, in [5], a texture is generated procedurally on the GPU based on the elevation and slope of the terrain at a given point. However, this approach cannot provide high image quality when approaching the surface at close range due to limited texture resolution.

Key models applicable to various three-dimensional objects and allowing to determine the parameters of the virtual scene are presented in the works [6 – 10].

The analysis of the work confirms the relevance of the development of multimedia data processing systems and their use in various fields of human activity: science, industry and education [11, 12].

However, these developments have the following disadvantages:
they allow one to create virtual panoramas (one image of the object), not three-dimensional scenes;  
- they have a lack of integration with websites and Internet services (e.g. social networks), adaptation of the interface to mobile devices;  
- they require expensive special equipment and licenses for specialized software (for example, 360-degree cameras, software for processing and improving the quality of initial images);  
- there is no possibility to add interactive labels to get more detailed information about the object;  
- they are characterized by the time-consuming process of creating the necessary 3D-model of the object.

To solve the above shortcomings, it is proposed to use cloud computing.

3. Mathematical model

Let us consider a hybrid algorithm implementation model that is described by a tuple of values:

\[
M_{ga} = \{Z_i, C_{MOOC}, F_{flav}, F_{users}, I, N\},
\]

where it is defined:

\[
Z_i = \{Z_i^1, Z_i^2, ..., Z_i^n\}.
\]

Expression (2) is represented by a set of scene dimensions, \(n\) is the current number of built scene dimensions available in the cloud system.

\[
C_{MOOC} = \{C_{MOOC}^1, C_{MOOC}^2, ..., C_{MOOC}^n\}.
\]

Expression (3) is represented by the existing set of courses using a hybrid algorithm for processing multimedia data, which are presented to the user, \(n\) is current number of courses for processing.

\[
F_{flav} = \{F_{flav}^1, F_{flav}^2, ..., F_{flav}^{n_f}\}.
\]

Expression (4) is represented by a set of cloud system configurations, \(n_f\) is current number of configurations available in the cloud system.

\[
F_{users} = \{F_{users}^1, F_{users}^2, ..., F_{users}^{n_u}\}.
\]

Expression (5) is represented by a set of configurations of personal computers of users of the educational platform, \(n_u\) is current number of configurations of personal computers of users.

\[
I = \{I_1, I_2, ..., I_{n_i}\}.
\]

Set (6) determines the optimal Internet connection between the cloud system and the user.

\[
N = \{N_1, N_2, ..., N_{n_N}\}.
\]

Set (7) shows the total number of 3D objects in the user’s scene.

Each set of scene dimensions is described by a tuple of values:

\[
Z_i^j = \{Z_{dsq}^j, Z_{dv}^j, Z_{raz}^j\}, 1 \leq i \leq n_z,
\]

where it is defined:
Z_{dsq} - scene elements built using the diamond square algorithm; Z_{dv} - elements are constructed using the Voronoi diagram; Z_{rf} - final dimension of the scene.

Each set of cloud system configurations is described by a tuple of values:

\[ F_{flav}^m = \{ C_m, M_m, D_m, G_m \}, 1 \leq m \leq n_f, \]  

(9)

where it is defined:

- \( C_m \) - number of processor cores;
- \( M_m \) - amount of RAM in gigabytes;
- \( D_m \) - disk space in gigabytes;
- \( G_m \) - the amount of GPU in gigabytes.

Each set of three-dimensional objects is defined by the formula:

\[ N^j = \{ Fl^j, \mu_{id}^j \}, \]  

(10)

where it is defined:

- \( Fl^j \) - filters applied to a three-dimensional object;
- \( \mu_{id}^j \) - a function that allows you to identify identical three-dimensional objects;

\[ \mu_{id} = \mu_{pl} \wedge \mu_{pr} \wedge \mu_{re} \wedge \mu_n, \]  

(11)

where \( \mu_{pl} \) - area of the object; \( \mu_{pr} \) - length of the object; \( \mu_{re} \) - textures that are superimposed on the object; \( \mu_n \) - position of the object.

4. Experimental part

Currently, the main task in the processing of multimedia data is to optimize the transmission of information from one device to another. The concept of optimization implies the ability of technologies to minimize the transmission time about the type of scene, three-dimensional objects, textures and final rendering of the scene without losing the image quality of the user.

The architecture of the proposed process of processing dynamic streams of multimedia data based on resource virtualization for cloud applications is shown in Figure 1.

![Figure 1. Architecture of multimedia data transmission system.](image-url)
Users choose an educational course on the Web portal of the cloud system. For each user, a three-dimensional scene with a random location of 3D objects is formed. Next, to build a three-dimensional scene, the user is given information about the scene and the key points of location of three-dimensional objects with textures relative to its speed of connection to the Internet and the necessary three-dimensional models, which are taken from the “object Library”. Creation of a three-dimensional scene, key points and arrangement of 3D objects takes place on the user’s side. Three-dimensional objects are stored in the cloud. After the construction of the scene is completed, rendering of all objects through the use of the computing capacity of the server. The most key objects that are processed in the first place are those where the viewing angle of the user is directed. The proposed method of solving the problem of processing and transmission of multimedia data consists in the sequential solution of two tasks: it is necessary to generate a quality scene with respect to the selected educational course, and optimize the transmission time of multimedia data.

An example of an online course using three-dimensional technologies is shown in figure 2.

![Figure 2. E-course fragment.](image)

Based on the analysis of the module for the combined approach for adaptive landscape generation, it was found that the visualized three-dimensional scene, after applying the combined method, reduced its resource consumption is based on the parameters shown in figure 3.

![Figure 3. Diagram of changes in the load on the technical components of a PC.](image)
According to figure 3 you can see that the load on all PC components has decreased significantly, which allows one to increase the processing speed of graphic data.

5. Conclusion
The paper discusses the best methods and algorithms for intelligent processing of multi-media data, presents the possibility of an adaptive software module for distributed hybrid data processing visualization of three-dimensional objects and optimization of the flow of multi-media data, allowing you to create and explore three-dimensional models of objects in solving problems based on virtualization resources.

On the basis of the developed module, the processing flows of data visualization of three-dimensional objects are optimized. An algorithm for planning the joint use of video accelerators for distributed processing of large data streams for the visualization of three-dimensional objects for cloud applications is developed. The visualized three-dimensional scene, after application of the combined method, reduced the resource consumption by 15 - 25% that in turn increased productivity of process of processing and visualization of three-dimensional data in the virtual educational environment.

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