Remote Access to 3D Models of Cultural Heritage

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Abstract— **Stereoscopic and immersive visualisations are used in various scientific and engineering fields. We describe our experience with long-distance transmissions enabling real-time interaction with a remote 3D model of historical architecture over a long-distance transmission. We illustrate the potential of such technology for distance research, education and research using models of historical architecture and other digitized cultural heritage.**

Index Terms—**distance learning, real-time 3D transmissions, virtual reality, digital cultural heritage**

I. INTRODUCTION

Stereoscopic (3D) models and visualizations are used in many fields of research, engineering and even in art and humanities. Examples are biology, chemistry, machinery design, architecture and new ways of creative art or performances. If we can share 3D models in real-time across a computer network in high quality and with low latency, we can enable effective distance learning, research and presentation.

Another purpose of remote access is for models, which cannot be moved physically due to their size, weight and historical value. Computer models may have intellectual property rights (IPR) applied restricting their sharing in data form, while visualizations of the model can be shared.

Flat high resolution video walls from LCD panels are often used by researchers to present multiple visualizations together on a large working space. Commonly used software for remote streaming to video walls is the Scalable Adaptive Graphics Environment (SAGE) [1]. Applications linked with the SAGE Application Interface Library (SAIL) can stream to video walls served by SAGE receivers. A new version SAGE2 is now based on web and JavaScript technologies, with a set of web browsers displaying the content on the LCD wall.

The goal of the described use case is twofold. First, to develop and demonstrate a prototype of a novel virtual and augmented reality learning and presentation application providing remote access to 3D models of digitized cultural heritage. Second, to set an example how to provide remote access to unique and expensive intellectual property (the digitized model) to students and public while keeping the model in a safe environment.

We describe an experiment whose goal was to verify practicability of interactive remote access to a 3D model for distance learning, research and presentations, while preserving the model IPRs.

If such a system is brought to production use, it will enable new options in education and research, with an interactive approach, viewing the exhibits in 3D space with additional information even remotely without having physical access to valuable collection items. The system will also significantly contribute to the protection of collection items by minimizing physical handling. Similar systems are already being used in industrial engineering. Their use for access to cultural heritage is unique.

II. RELATED WORK

Europeana (www.europeana.eu) is a multilingual access point to Europe's cultural heritage in a digital form, allowing a search through millions of digital objects provided by European museums, galleries, archives, libraries and other institutions, whose objective is the preservation of cultural heritage.

Athena Plus (www.athenaplus.eu) is a 30 month project (beginning March 1, 2013), which creates a network of European museums. Its purpose is the collection of the of digital content and its contribution to the Europeana. The project Athena Plus currently involves 40 institutions (ministries of culture, museums, galleries) from 20 European countries.

A number of museums in the world are engaged in the Google Cultural Institute (www.google.com/culturalinstitute), which allows the presentation of historical artefacts.

Digital heritage is currently represented by photographs, audio and video samples. Interactive real-time rendering of 3D models will bring new opportunities for research, learning and presentations.

PDF documents can include interactive 3D models specified in the Universal 3D (U3D) format [2]. This is already used for some artefacts presented in Europeana.

III. REQUIREMENTS AND OPTIONS

A 3D computer model is generally specified by a mesh of triangles or quads and bitmap textures. When working with such a model, we want to move it around to see it from different points. When this should be done remotely, there are two principal strategies - sharing the model data or sharing the resulting visualizations.

The advantage of sharing the model data is that we transmit a small volume of data and computing resources in each location can be utilized for custom visualizations. On the other hand, the model IPRs need to be cleared for sharing and we need the rendering software in all locations.

When the resulting visualizations are shared, the model IPRs are easier to manage, the model data is kept in one location and the rendering software is needed in

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one location only. However, larger volumes of data are transmitted and we need large computing resources in the central location.

With the first option, fixed texture bitmaps can be pre-shared, to reduce network bandwidth requirements afterwards, when only data model changes and view point information are exchanged. The choice of strategy depends on a particular use case. Because we wanted to protect the model IPR, we have chosen the second strategy.

For interactive feeling of remote model manipulation, latency between visualizations in all locations should be low and close to each other. An empirical experience has shown that the limit for the user to feel that the system is reacting instantaneously is approx. 150 ms [3]. Below this limit the users would feel they are manipulating the model directly.

IV. Design

A software renderer and the streaming application are structured as an acyclic oriented graph of dynamically loadable modules. An example structure is shown in Fig. 1. Each module can be executed on a separate thread on a CPU core or on GPU, on the same or different PC. Modules running on the same PC are synchronized by creating a socket pair by a *socketpair()* and waiting for a message by a *poll()* call. Different PCs are synchronized by Nvidia G-Sync cards at the frame level and by Nvidia OpenGL extensions at the data processing level in applications. A particular structure of modules is constructed during the application start up according to a configuration file.

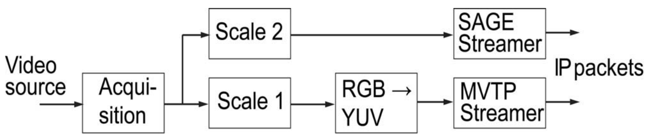

Fig. 1. Example structure of software modules

A. Data acquisition

The source 3D model specified in VRML is loaded into the application using the Assimp library, which also supports many other formats (e.g., OBJ). The model is rendered and presented on a local display device, which can be a SAGE (Scalable Adaptive Graphics Environment) or CAVE (Cave Automatic Virtual Environment). To obtain the image which can be streamed over the network, two different methods can be used - an OpenGL wrapper and screen capture.

The OpenGL wrapper intercepts the OpenGL *SwapBuffer* calls, copies the frame buffer content from the graphical card to the main memory for the use in further modules and passes control back to the original OpenGL library. The advantage is that it works with any rendering application using standard OpenGL calls and it adds minimum latency, because the data is loaded before displaying. The down side is that data retrieval slows rendering and if the application uses non-standard methods, acquisition may not work properly.

Screen capture reads data periodically from the graphical memory. It runs independently of the application, it can extract a portion of a screen, multiple screens at once and it is not slowing down the application. However, it does not work for 3D using the quad buffer.

We preliminary checked frame buffer read times using two graphical cards: Nvidia GeForce GTX980 (can render in 4K resolution, but 2D only) and Nvidia Quadro K5000 (can render in 3D, but at 1080p only). The times required for reading an image from the frame buffer are shown in Tab. 1.

Processing latency in the software sender from the interception of OpenGL calls to sending of IP packets to a network card consists of three parts shown in Fig. 2: reading from the framebuffer, format conversion and waiting for streaming. The time of reading from the framebuffer depends on its size, that is on the frame resolution and whether one or two frames (for 3D transmissions) are read. The format conversion time depends again on the frame resolution and on the output streaming format. It is the same for 3D, because the two frames can be converted in parallel threads.

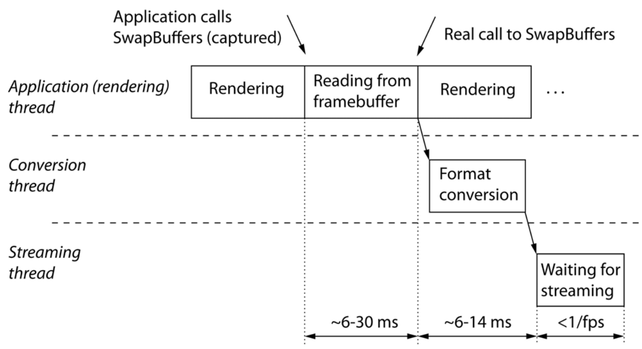

Fig. 2. Composition of time phases in rendering and streaming applications

The table also shows estimated maximum frames per second (fps), neglecting the rendering time. Fair values would be lower (depending on a rendering application). The Quadro cards allows even 4K resolution at reasonable fps.

B. Remote control

The rendering and streaming application has no explicit support for remote control, which is implemented at the system-level. Therefore, it can be used with any OpenGL applications. Signals from the remote control device, such as a game pad, are sent over the network and a virtual control device is emulated.

TABLE 1: Reading times and estimated FPS

Resolution	*GTX980*	*FPS*	*Quadro K5000*	*FPS*
1270x720	8.3 ms	120	0.9 ms	1000
1920x1080	13 ms	77	1.8 ms	555
3840x2160	61 ms	16		

Resolution	*GTX980*	*FPS*	*Quadro K5000*	*FPS*
3D 1270x720			1.1 ms	910
3D 1920x1080			3 ms	330

V. Experimental evaluation

We did an experiment that demonstrated remote interactive access to a 3D model that could not be moved. It was a computer model of the Langweil model of Prague, which is a physical paper model of the historical centre of Prague. The model was created in 1826-37 by Antonin Langweil in 1:480 scale and includes approx. 2000 houses. The model is owned by The City of Prague Museum. It is of significant historical value, because approximately half of structures has changed. Due to its size and fragile conditions the physical model cannot be moved. The model has been digitized in previous years in an extensive project. The IPRs to the digitalized model require it to stay in the museum. It is however possible to share visualizations of selected parts of the model.

The model was rendered in the Institute of Intermedia (IIM) at the Czech Technical University in Prague using two PCs, each with one Nvidia Quadro FX5800 graphics card with two DVI outputs to drive the CAVE environment. Each DVI output provided a 3D signal for one wall by interlacing frames for the left and right eye. The lecture room at the APAN workshop in Hawaii was equipped with a 3D projector. The two sites were connected by approx. 15000 km of network links. The graphics application run in IIM generated visualization for the local CAVE and also passed the visual data to the software sender, generating a slightly modified visualization for a single screen 3D view. This visualization was streamed to the workshop venue in Hawaii. People could navigate through the streets of a model interactively and study details of individual historical buildings. A situation on the receiving side is shown in Fig. 3.

The network one-way delay was approx. 68 ms. The total round-trip delay from control commands given by a keypad to the change in visualization in 1080p30 3D was approx.: 2x68 ms (network) + 30/77 ms (processing avg/max) + 20 ms (control keypad device) = 186/233 ms (avg/max).

People said that the delay between a movement of a control device and the corresponding change in visualization was noticeable, but it could be accommodated in thinking and interactive work was well possible. This can be considered a satisfactory achievement given the distance between the Central Europe and Hawaii.

Fig. 3. Real-time remote 3D access to a model of historical architecture

VI. Conclusions and Future Work

The prototype application can work with any model in formats such as VRML and OBJ. The method used is application independent, other rendering OpenGL visualization tools or any application with screen capture can be used.

We have shown that the low-latency remote access to 3D models in high resolution, enabled by current high-speed networks, can in turn enable more effective collaboration, distance learning and new presentation methods of historical architecture models and other digitized cultural heritage even over large distances. The added value to current videoconferencing systems is higher level immersion when accessing remote 3D models and low latency interactive model manipulation (modification and change of view). The streaming system works with existing OpenGL applications even in a binary form and with various visualization environments. Experiments conducted over very long distances (> 10000 km) have shown that the low processing delay on the sender and receiver side is added when to the inevitable network propagation delay, the resulting response time is still well acceptable and giving an interactive feeling.

The proposed approach will enable analysis of the model from more views and in more details than what static images can convey. A virtual walk-through the model can be rendered in real-time and delivered online to participants. This will turn users from passive observers to active researchers.

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The digital version of the Langweil model of Prague is reproduction of a collection item in a collection administered

by the City of Prague Museum. The author of the collection item is Antonin Langweil.

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