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Efficient framework for mobile walkthrough application

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ABSTRACT

The past few years have witnessed a dramatic growth in the number and variety of graphics intensive mobile applications, which allow users to interact and navigate through large scenes such as historical sites, museums and virtual cities. These applications support many clients and impose a heavy requirement on network resources and computational resources. One key issue in the design of cost efficient mobile walkthrough applications is the data transmission between servers and mobile client devices. In this paper, we propose an effective progressive mesh transmission framework that stores and divide scene objects into different resolutions. In this approach, each mobile device progressively receives and processes only the object's details matching its display resolution which improves the overall system's response time and the user's perception. A fine grained cache mechanism is used to keep the most frequently requested objects' details in the device memory and consequently reduce the network traffic. Experiments, in simulated and real world environment, are used to illustrate the effectiveness of the proposed framework under various settings of the virtual scene and mobile device configuration. Experimental results show that the proposed framework can improve the walkthrough system performance in mobile devices, with a relatively small overhead.

1. Introduction

The recent proliferation of mobile phones has created a unique opportunity for researchers to use all their capabilities to provide new applications. Streaming and sharing different kinds of content such as pictures, documents, objects and videos have become more popular than ever. Immersing multiple users in a 3D world, in which each user simply uses a smart phone, has become possible with the evolution of today's technologies in terms of mobile computing and computer networks. Although we have witnessed these advances, mobile devices still lack the proper resources to run graphic intensive applications, such as walkthrough systems. In general, a walkthrough application is a shared virtual environment where users at their devices interact with each other over a network, each user is symbolized by an entity called avatar. Users normally navigate through the scene, perform various actions and interact with the other users within the same area of interest. The virtual environment must be rendered in real time to display a consistent view for all users. As a result, excessive resources will be required to avoid performance bottlenecks and maintain a reasonable quality of service, typically in terms of response time, latency and rendering speed (number of frames per second).

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To overcome these limitations, this paper presents a framework that reduces the amount of transmitted object meshes through the wireless environment; and also matches the object data with the resolution of the graphics hardware. This allows the system to provide a proper rendering speed and acceptable quality of service. The proposed framework consists of three main modules: First, progressive meshes module which divide objects mesh into several partitions and transmit only the appropriate resolution (partition) according to the distance between the user's view point and the visible objects. Here, the system determines the user's moving direction and transmits continuously from a low, base mesh, to high resolution [1]. Second, the caching mechanism allows a client to utilize its memory and local storage to cache current visible objects that are likely to be visible in the near future [2]. Our cache replacement policy is based on the assumption that a farthest object from the user will not be requested again in the near future. Hence, when a free cache space is needed, the outermost object is selected. Third, constrained object's resolution selection module is used to identify the highest resolution of the object's mesh that will be transmitted, based on the device capabilities such as the screen size and network bandwidth. Thus, it avoids the transmission and processing of unnecessary data.

To evaluate the functionality of our framework presented in this paper, we have measured several performance parameters through an extensive set of experiments in simulated and real world environment.

The rest of the paper is organized as follows: Section 1.1 describes the most relevant related work. Section 2 presents an overview of the framework system architecture. Section 3 describes experimental design, simulation and real world experiments setup in detail. Experimental results and discussions are given in Sections 4 and 5 respectively. Conclusion and future work are presented in Section 6.

1.1. Related work

The development of the proposed framework has involved review of research in various computer science fields. This section is oriented toward three main subjects: (1) Efficient management of the network scarce bandwidth resources using different techniques such as progressive mesh streaming. (2) Development of light weight applications. (3) Caching mechanisms that reduce the amount of data requested over the network and improve the response time. Reducing data transmission in the wireless medium is essential to improve any virtual environment system. This can be achieved by various approaches such as:

- Creating and developing models for storing, transmitting, and displaying 3D objects in multimedia and VR applications [3–10].
- Designing special network transmission protocols that suits new generations of mobiles [11,12].
- Pervasive mobile computing and cloud computing (light-weight applications) to overcome processing power limitation [13–16].
- Data caching on device cache memory [1,2,15,17,10].

Progressive mesh techniques used to simplify 3D objects and beat the limitation of wireless network bandwidth. Authors in [10] presented a progressive mesh representation method to simplify the complex triangle mesh into a coarse one. The mobile users can get a general idea about the 3D model without large waiting time. An explicit rule has been used to calculate the cost of each collapsing edge. However, this approach lacks the view-dependent ways to represent the whole mesh.

J. Ma et al. [5] presented 3D mesh compression approach based on reverse Modified Loop scheme and embedded zerotree mesh coding. The dense mesh was decomposed into progressive mesh which can be flexibly transmitted over wireless network.

Several derivatives of the progressive mesh technique exist [6,8,16,7,17,6,15,18,5,2,19,4]. Isenburg and Lindstrom [6] proposed the streaming meshes technique where a mesh is stored into a fixed size buffer and triangles and vertices are either added or removed from the mesh in order to reconstruct it. Kircher and Garland [8] proposed a multi-resolution representation for deforming objects with a high quality approximation. The multilevel mesh proposed by the authors aims at having iterative edge contraction, and uses less space since it stores progressive representation (mesh connectivity at each level) instead of the entire hierarchy. However, edge contraction makes the mapping false since vertices forming the children can move [4]. Fang and Tian [9] implemented a mesh simplification based on the triangle contraction simplification. Pajarola and Rossignac [7] proposed the compressed progressive meshes (CPM) approach aiming at improving the PM technique by focusing on removing the overhead and latency engendered by progressive mesh. For this matter, CPM uses the implant sprays technique to refine the mesh by assembling the vertex splits into batches. In consequence, CPM occupies 50% less storage than PM model. Modified Compressed Progressive Meshes (MCPM) technique [3] improves CPM by including a decision module that selects the most suitable transport protocol for each geometric sub-layer taking into account the network bandwidth and the loss ratio.

A. Boukerche et al. [11] proposed a remote walkthrough over heterogeneous network for mobile device using Image Base Rendering (IBR). In 2008 they used end-to-end virtual environment streaming technique [12]. The main difference between our framework and this work is that, we used the progressive mesh representation through open wireless network to render the 3D object over the mobile device. We choose this technique to virtualize the 3D objects at low quality and then refine it if needed. This technique is avoiding the IBR disadvantages such as pixel loss and distortion [4,20]. The disadvantage of progressive mesh is that, it takes long time for generating the mesh but, we solve this problem by creating the mesh partitions in the server side. The client just needs to render the objects on the mobile screen.