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Video rate control strategies for cloud gaming

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ABSTRACT

Cloud gaming, also called gaming on demand, is a new kind of service that provides real-time video game experience to the players over the Internet. Although cloud gaming services are getting more and more popular recently, its performance is highly limited by the network bandwidth and latency. This work makes use of the unique characteristics of human visual system (HVS) of video game players to improve bandwidth efficiency. In this work, discussions about the characteristics of game players' HVS are conducted. The discussions can be further extended to all interactive video on demand systems. Then, some schemes of extracting region of interest and key frames from gaming videos are raised. Based on that, a Macro-block level rate control scheme is proposed based on region of interest and scene-change detection. The simulation results show that, under the same bandwidth constraint, the video quality of proposed method outperforms other methods.

1. Introduction

Cloud gaming is a new popular Internet service that combines the concepts of cloud computing and on-line gaming. It provides the entire gaming experience to the gamers by using the resource of the remote computing servers. Because all the graphics computing and data processing are done in the remote data center, the user's terminal device is nothing more than a controller (mouse, keyboard or game controller) plus a monitor. The player no longer needs to buy expensive and cutting-edge gaming hardware, like graphics card and big RAM, but still enjoy the latest game. The terminal devices only need broadband Internet connections and the ability to display High Definition (HD) video.

An overview flow chart is shown in Fig. 1. As explained in [1], on the client side, the user controls the game just like on a local device, such as PC, TV or mobile devices. Every time the player performs an operation, such as pressing a key, moving the mouse, or using the controller, the cloud gaming system will send the controlling signals to the remote game servers through Internet. On the server side, the remote servers receive the controlling signals and execute the game programs accordingly. Usually, it involves intensive graphics computation to generate high-quality pictures in real time. Then, the servers will stream the compressed gaming video back to users' devices. All the gaming program execution, graphic computation and video compression are done on the remote game servers. There will be a continuous control stream from user to server and a continuous video stream from server to user all the time until the session is disconnected.

While it may reduce hardware costs for users, and increase the profit for developers and publishers by reducing the expenditures on retail chains, it also raises a lot of new challenges, especially for the service quality in terms of bandwidth and latency for the underlying network. Table 1 shows a list of Pros and Cons of cloud gaming compared with traditional gaming.

As shown in Table 1, a good gaming system must balance the high performance and good accessibility. Recently, cloud gaming becomes a very hot trend in game industry. Many cloud gaming platforms are getting popular, especially after the leading game console corporations all announced that they will integrate cloud gaming systems into their latest game consoles. However, although they provide very impressive gaming experience, it seems that the only bottleneck that hiders people from using them is the high bandwidth requirement. Thus, solving this problem may be a matter of life and death for this business.

When cloud gaming is based on a network of a relatively low quality condition, e.g. playing cloud games on a wireless mobile device, users still want the gaming experience to be good and smooth as well. In order to provide a decent and stable video streaming quality under a given network condition (or a limited bit rate), rate control (RC) of video coding must be performed. Compared to RC for ordinary videos, RC in clouding gaming have more restrictions, like sensitivity to latency, demand for high

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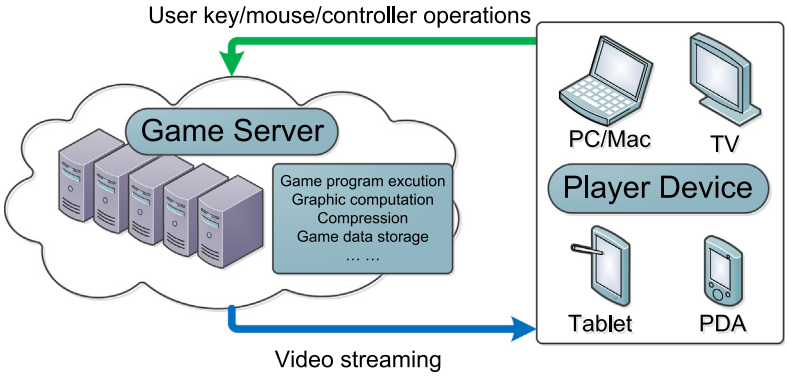

Fig. 1. Cloud gaming overview.

Table 1
Pros and Cons of cloud gaming.

Advantages	Trad. gaming	Cloud gaming
No download and install time	X	✓
No expensive hardware is needed	X	✓
Accessible from any platform	X	✓
Syncing saved game everywhere	X	✓
Easy to get free trail for gamer	X	✓
Easy to distribute for publisher	X	✓
Social features (spectators, brag clips, etc.)	X	✓
Allowing to play off-line	✓	X
No lag	✓	X
Supporting HD resolution	✓	X

image quality in key frames. Although many challenges are faced, many unique characteristics of human visual system (HVS) of video game players can also be exploited to improve bandwidth efficiency. This work focuses on these problems. Since proposed work is the first one to solve this problem, it shows great potential for the development of the cloud gaming industry.

2. Related work

Since cloud gaming is a newest concept, its related research is not fully conducted yet. To the best of the authors' knowledge, almost all related researches on this topic are conducted after 2010. By now, most of the papers are discussing the quality of experience (QoE) evaluation scheme, like [2], and measurement of latency, like [3]. Hobfeld et al. [4] pointed out several challenges related to cloud application's QoE management. However, no one proposed the rate control scheme for cloud gaming, which is a crucial problem as well.

As stated in [1], the major cloud gaming providers Gaikai and Onlive both use versions of the H.264/AVC encoder. Although there are a lot of rate control schemes are proposed for H.264 standard, like [5–10], most of them are for ordinary videos, but not specifically considering the features of video gamers' HVS. The existing rate control methods have bad performance on cloud gaming video, essentially because they are designed for non-interactive applications, and not directly applicable to the interactive situations.

On the other hand, as the growing emphasis on QoE-based evaluation, more and more researchers are interested in ROI-based video coding. Accordingly, some work focuses on ROI-based video rate control for H.264, like [11–15]. However, because the ROI extraction method for arbitrary videos is a very hard problem itself, ROI based rate control may not achieve its ideal performance. At the worst cases, the video viewer may get a worse experience because of the wrong ROI detection. For example, many of the ROI detection algorithms for the video rate control are designed for the conversational and head-and-shoulder types of video sequences, like [12,13]. In [13], the ROI detection methods are mostly implemented as face detection and motion detection, which limit their scope of application. Furthermore, limited by the computational resources provided by the real-time encoder, the ROI detection is further simplified to a skin tone detection and the residue between two consecutive frames, which makes the detected ROI very inaccurate for non-conversational scenarios. Last but not least, the algorithms are designed for processing videos with QCIF resolution (176×144 pixels), not high resolution videos. There are also some papers using motion information as the basis of ROI and adjusting the coding scheme accordingly, such as [14,15].

The remainder of this paper is organized as follows. Section 3 presents the general ideas of ROI and key frame extraction methods for gaming videos. In Section 4, two methods to perform rate control on H.264/AVC gaming videos are proposed: one is an intra frame allocation scheme; the other is a novel MB-level rate control algorithm, and an ROI-based bit allocation algorithm is also proposed in this section. In Section 5, a simple objective QoE-based evaluation is described, and with the proposed ROI detection, rate control and evaluation schemes, the performance of proposed system is compared to the original H.264/AVC rate control algorithm JVT-G012 and other state-of-the-art ROI-based rate control methods proposed in [13,19]. At last, the conclusions are given in Section 6.

3. ROI and key frame patterns for gaming video

Since people are more sensitive to the areas where they are interested in, it is reasonable to enhance the region of interest (ROI) while sacrificing the non-ROI regions when the overall coding and transmission resources are limited.

Compared with general videos, encoding cloud gaming videos has three convenient and exceptional features that can be exploited to enhance the performance. First, people are far more concentrative on the ROI while playing games than watching ordinary videos, so the difference between ROI and non-ROI can be bigger and still does not lower the viewer's experience. Second, the transmitted gaming video is originally generated by the game programs and graphics processors, so it is very convenient for the game developers to actively provide the side information to help the video encoder, such as foreground and background, depth of an object, scene-change position, etc. It is far more accurate and efficient than passively analyzing the ordinary video. Third, the gaming servers are equipped with powerful GPUs and DRAMs. The massive computational resources can supply the overheads brought by rate control for HD videos.

More generally speaking, these features can be further extended to all interactive VOD systems, which involve both users' control