摘 要

随着互联网的不断发展和视频内容的不断丰富，面向互联网的流化视频编码技术逐渐成为近年来数字多媒体技术研究的热点方向。针对流化视频在互联网中传输所面临的带宽波动问题，本论文主要研究了流化视频编码中可伸缩视频编码方案和视频流切换技术。在充分汲取现有精细可伸缩视频编码技术和码流切换技术的优点的基础上，针对它们在编码效率、灵活性或带宽适应性上的不足进行了深入地研究，创新性地提出了四个编码方法从而有效地提高了流化视频编码的性能。具体的，本论文的主要研究成果如下：

首先，提出了高效的基于宏块的渐进精细可伸缩的（MPFGS）视频编码方法，它建立在现有的 FGS 和 PFGS 编码框架的基础上。为了实现编码端的传递误差控制，本文首先对 MPFGS 中传递误差的产生和传播进行了分析并建立了相应的传递误差模型。在此基础上，首次提出了三种增强层宏块帧间（INTER）编码方式及其相应的编码方式选择算法，从而在传递误差和编码效率上取得了良好的平衡。实验结果表明本文提出的基于宏块的 PFGS 视频编码方法既能有效的控制低码率下的传递误差，也能提高在其它码率下的编码效率。同 FGS 相比，它的编码效率提高了 2.3dB。

其次，提出了灵活高效的基于宏块的具有时域和 SNR 精细可伸缩的视频编码（简称为 MPFGST）方案。为了能更有效的适应较大范围的带宽波动，MPFGST 在增强层采用了双向预测帧（B 帧）编码技术从而实现了时域（帧率）可伸缩性。根据运动补偿中使用的参考宏块的不同，本文提出了时域可伸缩增强层宏块编码的两种方式。通过选用最佳的参考宏块，基于宏块的 PFGST 视频编码技术的编码效率同 MPEG-4 标准中的 FGST 编码方法相比提高了 2.8dB，并且同样具有 FGST 的所有特性，即可以分别支持精细的 SNR 可伸缩特性、时域可伸缩特性和 SNR-时域混合可伸缩特性。

第三，提出了支持无缝切换的多层可伸缩视频编码方法。它吸收了非可伸缩视频编码的高编码效率和可伸缩视频编码方法的灵活性，从而在更宽的带宽范围内获得了更好的流化视频服务质量。该方法使用可伸缩的视频码流来适应小范围的带宽波动，而通过码流切换来适应大范围的带宽波动。文中我们提出了两个主要的码流切换技术。首先提出了一个新颖的编码方法，它能够在任意帧实现从一个编码在较高码率的码流无误差无附加码流的切换到一个编码在较低码率的码流。其次本文提出了一个切换帧（SF）编码技术，它有效地降低了从编码在较高码率的码流到编码在较低码率的码流的切换中所需传递的附加信息码流的码率。实验结果显示本文提出的编码方法提供了更有效更灵活的视频流服务性能，与 FGS 和 MPFGS 编码方法相比，它的编码效率分别提高了 3.0dB 和 2.0dB。

最后，提出了两个新的视频流预测帧无传递误差的切换技术—灵活的切换帧（Flex SP）编码技术和混合的切换帧（Hybrid SP）编码技术。同 H.26L TML94 原有的切换帧（SP-Frame）编码技术相比，它减少了对显示重构图像所做的量化次数，提高了解码显示视频图像的质量。

此外，通过分离向上切换和向下切换的量化参数，同向上切换帧相比，它可以更频繁的插入数据量更小的向下切换帧，从而提供了灵活的带宽适应性。在 Hybrid SP 编码技术中，我们提出了两种变换系数的编码模式，从而将 Flex SP 和 H.26L 原有的 SP 编码有机的结合起来，实现了灵活高效的码流切换。此外，本文提出了一个率失真优化的编码方式选择算法来确定每个变换系数的编码模式。Hybrid SP 编码算法同原有的 H.26L TML94 的 SP 编码方案相比，在相同的解码质量下可以节约 18%的比特数。该项技术已经正式被 MPEG 和 ITU-T 联合视频组（JVT）最终标准—H.264 或 MPEG-4 第十部分所采纳。

关键词　流化视频；视频编码；可伸缩视频编码；码流切换；时域可伸缩性

Abstract

Due to the explosive growth of the Internet, as well as the abundance on video contents, streaming video over the Internet has drawn tremendous attention in digital multimedia research. In this paper, the scalable video coding method and the switching among multiple bitstreams are investigated for dealing with the bandwidth fluctuation when streaming over the Internet. By fully taking advantages of these coding methods and systematically studying on their shortage of coding efficiency, flexibility and bandwidth adaptation, four novel video coding methods are proposed in this paper to improve the streaming video performance. The creativities and contribution are discussed in detail as follows:

Firstly, a highly efficient macroblock (MB)-base progressive fine granularity scalable (MPFGS) video coding scheme is proposed based on MPEG-4 FGS video coding scheme and PFGS video coding method. The status that when the drifting errors occur and how they propagate in MPFGS is analyzed and an iterative model is established to estimate the drifting errors at the encoder. For optimally balancing the drifting errors and the coding efficiency, three new INTER modes and the corresponding mode decision-making mechanism are proposed based on the presented model for the coding of MBs at the enhancement layers. Experimental results show that MPFGS method can dramatically control the drifting errors at low bit rates, while significantly improving coding efficiency at other bit rates up to 2.3dB in average PSNR compared with MPEG-4 FGS.

Secondly, a flexible and efficient architecture, namely, the MB-based progressive fine granularity scalable video coding with temporal-SNR scalabilities (MPFGST in short) is proposed. In order to efficiently adapt to wider bandwidth fluctuation, the temporal scalability is introduced in MPFGST by adopting bi-direction predicted frame (B frame) in its enhancement layer coding. Due to different references used in prediction, two coding modes are proposed for coding the temporal enhancement MBs. By always choosing the most suitable reference for the temporal scalable coding, the MPFGST method can significantly improve the coding efficiency up to 2.8dB compared with the MPEG-4 FGST scheme, while also supporting full SNR, full temporal, and hybrid SNR-temporal scalabilities.

Thirdly, a multi-level scalable video coding method supporting seamless switching is proposed. It improves the performance of video streaming over a broad range of bit rates by taking advantage of both the high coding efficiency of non-scalable bitstreams and the flexibility of scalable bitstreams, where small bandwidth changes are adapted by the scalability of a single scalable bitstream, while large bandwidth fluctuations are tolerated by flexible switching between different scalable bitstreams. Two main techniques for switching are proposed here. Firstly, a novel coding scheme is presented to enable drift-free switching at any frame from the current scalable bitstream to one operated at lower rates without sending any overhead bits. Secondly, an SF coding scheme is proposed to greatly reduce the number of extra bits needed for switching from the current scalable bitstream to one operated at higher rates. Experimental results show that the proposed scheme brings more flexibility in video streaming and provides higher coding efficiency up to 3.0dB and 2.0dB compared with the FGS and the MPFGS.

Finally, two new schemes for drift-free switching of streaming video bitstreams at predictive frames are proposed, namely，Flex SP coding scheme and Hybrid SP coding scheme. Compared with the SP coding scheme in the H.26L TML94, the Flex SP improves the display quality by reducing the number of quantization operated on the reconstructed image for the display purpose. Moreover, it decouples the quantization parameters for up-switching and down-switching streams, due to which the size of the down-switching stream can be much smaller than that of the up-switching one and more rapid and frequent down-switching than up-switching can be supported. Thus the Flex SP can adapt to the bandwidth fluctuation more flexibly. In the Hybrid SP scheme, we integrate the Flex SP coding scheme and the original one in H.26L TML94 together by defining two coding modes at each coefficient. A rate-distortion algorithm is also proposed to optimally select the coding mode of each coefficient. Compared with the original SP coding method in H.26L TML94, the hybrid SP coding scheme can provide better flexibility and save up to 18% bits at the same decoded quality. The techniques discussed in this paper have been officially adopted in the final JVT standard – H.264 or MPEG-4 part 10.

Keywords streaming video; video coding; scalable video coding; bitsteam switching; temporal scalability