摘 要

第三代视频编码标准 (The Third Generation of Audio Video Coding Standard, AVS3) 是我国具备自主知识产权的信源编码标准。 AVS3 高效的编码性能缓解了超高清视频大数据对视频存储和传输带来的压力，对超高清视频产业的发展至关重要。 AVS3 仍采用基于块的混合编码框架，并在每个编码模块中加入了大量新颖的编码工具。与 AVS2 相比，AVS3 的编码性能提升了一倍，同时编码复杂度也提高了约 30 倍。本文面向 AVS3 视频编码标准，首先通过深入分析模式相关性与视频信号时空域相关性，研究了在保持编码效率的同时降低编码复杂度的方法，随后通过细粒度像素分类，研究了重构视频精细重建的环路滤波方法。本文主要创新点如下：

第一，提出了一种面向复杂划分的多类型划分决策方法，缓解了 AVS3 中多类型划分框架引入极高编码复杂度的问题。该方法首先深入分析了多个编码特征对划分决策带来的信息增益，构建了包括率失真分布特性、纹理特性和划分深度差等在内的分类器特征集合。随后，通过提升学习的方式，迭代训练弱学习器后构建了适用于复杂划分的强分类器，提升了算法的鲁棒性和普适性。同时，该方法引入了动态伸缩因子，满足了不同应用场景的性能需求。在 AVS3 参考软件平台上的实验结果表明，通过调节动态伸缩因子，该方法可以获得 17% ~ 76% 编码复杂度降低。同时，在与其他方法的对比实验中，该方法均可以取得优异的结果，验证了该方法的有效性与高效性。

第二，提出了一种基于统计分析的自适应帧内模式预测方法，提高了最优模式选中概率，降低了编码复杂度。该方法首先分析了帧内预测模式的内在联系并设计了一种共享帧内粗选列表和模式决策的方案，通过编码信息共享机制降低了帧内模式粗选和率失真决策的编码复杂度。随后，通过对视频信号空域强相关性的探索提出了空域模式再利用机制，优化了空域模式列表的构建方式，提高了帧内最优模式的选中概率，在降低了编码复杂度的同时仍可以取得显著的编码性能提升。在 AVS3 参考软件平台上的实验结果表明，该方法可获得 15.45% ~ 57.23% 的编码复杂度降低。

第三，提出了一种细粒度像素分类偏移补偿滤波方法，显著提升了重构视

频的主观质量和客观质量。该方法首先联合视频信号边缘类别和条带类别设计了一种新颖的像素分类方法。考虑到不同分量像素分布特性不同，该方法为亮度分量和色度分量设计了不同的像素分类方法。随后，基于视频信号时空相关性提出了时域信息复用机制和迭代滤波算法以进一步提高编码效率。在 AVS3 参考软件平台上的实验结果表明，该方法在全I帧、随机访问、低延迟 B 帧和低延迟 P 帧下分别可以取得 0.64% 、 1.29% 、 1.86% 和 2.20% 的编码效率提升。同时设计了像素对比结果缓存机制以降低编解码复杂度，在 AVS3 参考软件平台上的实验结果表明该方案可以在性能无损的情况下降低所提出方法约 75% 和 81% 的编解码复杂度。

综上所述，本文研究了面向 AVS3 的高效编码方法，从视频信号时空域相关性出发，提出了面向复杂划分的多类型划分决策方法、基于统计分析的自适应帧内模式预测方法和细粒度像素分类偏移补偿滤波方法。所提出方法均在新一代视频编码标准 AVS3 上进行了验证，并且均被 AVS3 标准或 AVS3 参考软件采纳。

关键词： 视频编码，预测模式决策，编码单元划分，率失真优化，像素偏移补偿，AVS3

Abstract

The Third Generation of Audio Video Coding Standard (AVS3) is a source coding standard with own independent Chinese intellectual property rights.The high efficiency coding performance of AVS3 effectively relieves the pressure on video storage and transmission caused by the ultra-high-definition video data, which is crucial to the development of the ultra-high-definition video industry. AVS3 still adopts the block-based hybrid coding framework and incorporates a bundle of novel coding tools in each coding module. Compared with AVS2, the coding performance of AVS3 is doubled while the encoding complexity is also increased by about 30 times. In this paper, the mode correlation of AVS3 and spatio-temporal correlation of video signal is analysed firstly, then the method of reducing the coding complexity while maintaining the coding efficiency is explored. Furthermore, a fine-grained pixel classification based offset compensation filtering method is proposed. The main innovation of this paper are as follows.

First, this thesis presents a multi-type partition decision method oriented to complex block partition scheme to alleviate the extremely high encoding complexity introduced by the multi-type partition framework in AVS3. The proposed method comprehensively analyzes the features related to block partition firstly. Then, information gain is used to screen the features, including rate-distortion distribution characteristics, texture variation characteristics and division depth difference. Subsequently, a strong learners is constructed by a sequence of weak learners through a weighted majority vote manner, which improves the robustness of the algorithm. Moreover, a dynamic scaling factor is introduced to meet the various application scenarios. When validated on the AVS3 test model, this method can achieve 17% ~ 76% encoding complexity reduction by adjusting the scaling factor. Compared with the state-of-the-art fast block partition method, the proposed algorithm can achieve excellent results, which verifies the effectiveness and efficiency of the proposed method.

Second, this thesis presents a statistical analysis based adaptive intra mode pre-

diction method, which improves the probability of the optimal mode selection and significantly reduces the coding complexity. The proposed method first proposes a coding information sharing mechanism by analyzing the internal relationship of intra prediction modes. With the proposed coding information sharing mechanism, the encoding complexity of rough mode decision and rate distortion optimization is reduced. Subsequently, the spatial mode reusing method is devised based on local correlations, which improves the probability of selecting the optimal mode. By exploring the spatial correlation, the selection probability of optimal mode is increased, leading to reduce the encoding complexity and improve coding performance. When validated on the AVS3 test model, this method can achieve 15.35% $\sim$ 57.23% encoding complexity reduction.

Third, this thesis presents a fine-grained pixel classification based offset compensation filtering algorithm, which significantly improves the subjective and objective quality of reconstructed videos. Firstly, a novel pixel classification method is designed by jointly exploring the edge characteristics and texture characteristics of video signals. Due to the distinct distribution characteristics of different channel, different classification methods are devised for luma and chroma components. Subsequently,a temporal-domain filter information reusing scheme and an iterative filtering training algorithm are proposed to further improve the coding efficiency. The proposed method achieves significant coding performance improvement, when validated on the AVS3 test model, this method achieve 0.64%, 1.29%, 1.86% and 2.20% under All intra, Random Access, Low-delay B and Low-delay P configurations compared to AVS3 reference software, respectively. Furthermore, pixel comparison result cache and instruction set optimization scheme are designed to reduce the encoding and decoding complexity. When validated on the AVS3 test model, this scheme can reduce the 75% encoding complexity and 81% decoding complexity respectively.

In summary, efficient coding methods are studied for AVS3 in this thesis. From the perspective of spatial-temporal correlation, the multi-type partition decision algorithm oriented to complex partition, statistical analysis based adaptive mode prediction algorithm and fine-grained pixel classification based offset compensation filtering algorithm are proposed. All the proposed methods are verified on AVS3 video coding standard

and adopted by AVS3 standards or reference software.

Keywords: Video coding, Prediction mode decision, Coding unit partition, Rate-distortion optimization, SAO, AVS3