

摘 要

数据压缩技术是多媒体领域的重要研究方向之一。由于多媒体数据量非常巨大，海量多媒体数据的存储和传输成为多媒体应用所面临的主要问题。通过使用数据压缩技术，对多媒体数据进行压缩，可以有效的减少多媒体数据量，在现有的设备条件下实现多媒体数据的有效存储和传输，使多媒体应用成为可能。视频数据在多媒体数据中所占比例最为显著，因此视频压缩效率的高低对多媒体数据压缩的影响也最大。视频压缩技术经过长期的发展，压缩算法被不断地改进，压缩性能逐步提高，各种视频压缩技术相关的产品已被广泛的使用。目前，视频压缩技术已经被标准化，国内外出现了很多视频压缩标准，其中主要有 MPEG-2, H.264/AVC 和 AVS 等。尽管视频压缩技术已经发展很长时间，但并不完善，在很多地方还存在着问题，其中一些问题长期困扰着视频压缩研究者和开发者们，不解决这些问题，将直接影响到新理论和新技术的应用，阻碍视频压缩技术的发展，因此，解决这些问题已经成为本领域的重要任务。本文的部分研究内容就是围绕着视频压缩技术中存在的若干问题，重点放在离散余弦变换技术上，通过对离散余弦变换技术的深入研究，着重解决离散余弦变换相关技术在视频压缩中存在的高复杂度问题和离散余弦变换定点化导致解码器误差漂移的问题。另外，为了满足视频压缩发展对多标准技术的迫切需要，本文也对 MPEG 的多标准描述技术框架可重构视频编码做了系统的研究，在可重构编码技术框架下重构出 AVS 解码器，并实现了 AVS 的解码工具与 MPEG 的解码工具的混合重构。本文主要的研究内容如下：

首先，针对 H.264/AVC 编解码器的离散余弦变换相关技术自适应块变换编码模式在取得高压缩效率的同时也有很高复杂度的问题，在自适应块变换模式中引入了扩展变换的概念，在 H.264/AVC 原有 4x4 整数变换基础上，利用扩展变换关系，推导出一个新的 8x8 整数变换。在自适应块变换模式下，新的 8x8 整数变换替换 H.264/AVC 原有的 8x8 整数变换，与原来的 4x4 整数变换一起共同使用一个 8x8 的量化表，节省了更多的存储开销。另外，新的 8x8 整数变换比原来的 8x8 整数变换更简单，计算复杂度更低。实验结果表明基于扩展 8x8/4x4 整数变换的自适应块变换模式在保持了自适应块变换模式的高压缩效率同时，也降低了空间和时间复杂度。

其次，针对浮点离散余弦变换的整数近似实现会导致解码器产生误差漂移的问题，提出了一套具有非常高精度的整数离散余弦反变换，该整数离散余弦反变换通过公因子提取和两阶段缩放算法得到具有和浮点离散余弦反变换非常相近的计算精度，在解码器中使用提出的整数离散余弦反变换代替浮点离散余弦反变换，能够避免通常整数离散余弦反变换导致的解码图像误差漂移问题。在极端的测试条件下，与视频编码标准推荐的

整数反变换相比，图像的误差漂移显著降低。提出的整数反变换的变换核采用无乘操作，大大降低了反变换的计算复杂度。

最后，为了实现包括 AVS 在内的多个视频标准压缩码流的解码，并且支持不同标准解码工具的相互连接，重构出新的解码器，使解码器不仅可以解码单一标准的压缩码流也可以解码不同标准的编码工具组合在一起压缩出来的码流，我们在 MPEG 的多标准描述技术框架中，描述了 AVS 的语法结构，添加了 AVS 的解码工具，重构出 AVS 解码器，使 AVS 码流能够被 MPEG 的多标准解码器解码，实现了 MPEG 多标准技术框架对 AVS 标准的支持。另外，还将 AVS 的整数反变换和反量化替换了 MPEG-4 标准的相应解码工具，重构出新的解码器。通过这种灵活的重构方式可以发挥不同标准解码工具的优势，使新的工具组合能够有更高的编码性能或更低的编码复杂度。

总之，本文重点围绕离散余弦变换在视频压缩中存在的若干问题以及在 MPEG 多标准技术框架下 AVS 解码工具描述的技术问题进行探索和研究，提出了对这些关键技术的改进方法或者解决方案，本文所提出的部分技术方法已经被采纳进推荐的国际标准，在实际中得到应用。

关键词：视频压缩；离散余弦变换；自适应块变换；误差漂移；可重构视频编码

Research on Some Key Technologies in Video Compression

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Data compression technology is an important research direction in multimedia area. As the multimedia data is very huge, the huge data storage and transfer become the major problem faced by multimedia applications. Using the data compression technology to compress multimedia data may reduce the multimedia data efficiently. On the condition of existing equipments, data compression realizes the storage and transmission of multimedia data and makes the applications of multimedia possible. Video data has very high percentage in multimedia data. Thus, the efficiency of video compression has most significant effect on the multimedia data compression. With the long-term development of video compression technology, compression algorithms are improved continually and compression performance is increased step by step. All related products of video compression are widely applied. Presently, video compression technology has been standardized. There emerge many domestic and foreign video compression standards, such as MPEG-2, H.264/AVC, AVS and so on. Although video compression technology has been developed for a long time, they are not perfect yet. There still exist some problems in many places, some of which are puzzling researchers and developers working on video compression area until now. If these problems were not well addressed, they would hinder new theories and technologies to be applied in practice. Thus, addressing these problems has been an important task in video compression area. The research contents of this dissertation are about some problems existing in video compression technology. The research emphasizes on the Discrete Cosine Transform (DCT) technology. With the deeply research on DCT, the high-complexity problem and fixed-point inverse DCT (IDCT) leading to error drifting were addressed in this dissertation. Moreover, in order to meeting the video compression development's urgent demand on multi-standard technology, the multi-standard description framework of MPEG, Reconfigurable Video Coding (RVC), was also systemically studied in this dissertation. The AVS decoder is successfully reconfigured in RVC and the AVS tools and the MPEG tools was also reconfigured together. The main research contents in this dissertation are as follows:

Firstly, to address the high-complexity problem of adaptive block-size transforms (ABT) scheme of H.264/AVC, a technology related to DCT which can achieve high-efficiency compression, the concept of extended transform is introduced into ABT scheme. Based on the 4x4 integer transform in H.264/AVC, a new 8x8 integer transform is deduced using the extended transform theory. In ABT scheme, the new 8x8 integer transform substituting for the traditional 8x8 integer transform of H.264/AVC shares the same 8x8 quantization table with the 4x4 integer transform. As a result, the less memory is required. Moreover, the new 8x8 integer transform is simpler than original 8x8 integer transform and the computational complexity is lower. The experiment results show that the proposed ABT scheme based on extended 8x8/4x4 integer transforms reduces the space and time complexities whereas maintaining the high-efficiency performance of ABT.

Secondly, to the problem that the integer approximation of floating-point DCT can lead to the error drifting of decoders, a high-accuracy integer IDCT is proposed. The integer IDCT is designed with the common factor extraction and two-stage scale algorithms, which has very close

accuracy to floating-point IDCT. The proposed integer IDCT substituting for floating-point IDCT in decoder can avoid the error drifting of decoder. In the extreme test conditions, compared with these integer IDCTs recommended by the video coding standards, the proposed integer IDCT can reduce the error drifting of decoded pictures significantly. Moreover, the transform core of the proposed integer IDCT is implemented with multiplication-free operations which reduces the computational complexity significantly.

Last, in order to decode bitstreams conforming to different standards including AVS and support interconnection of tools from different standards to reconfigure the new decoder so that RVC decoder can decode both bitstreams coded by the single standard and the combined tools from multiple standards, in the MPEG RVC framework, we described the syntaxes of AVS and added the tools of AVS to reconfigure the AVS decoder. The work made RVC capable of decoding AVS bitstream and realized that RVC supports AVS decoder. Moreover, integer inverse transform and inverse quantization of AVS were substituted for corresponding tool in MPEG-4 decoder to reconfigure a new decoder. With this flexible tool reconfiguration, the merits of decoding tools from different standards are exerted so that the combined tools improve the coding performance and reduce the computing complexity.

In summary, this dissertation researches on some existing problems of application of DCT in video compression and the description of AVS tools in RVC and proposes some improved methods or solutions to these key technologies. Some solutions have been adopted in recommended international standard to be applied in practice.

Keywords: video compression, DCT, ABT, error drifting, RVC