Advanced Telecommunications and Signal Processing Program

Academic and Research Staff
Prof. Jae S. Lim

Research Affiliate
Carlos Kennedy

Graduate Students

Brian Heng
Eric C. Reed
Wade Wan
Chuohao Yeo

Support Staff
Cindy LeBlanc

Introduction

The present television system was designed nearly 50 years ago. Since then, there have been significant developments in technology, which are highly relevant to the television industries. For example, advances in the very large scale integration (VLSI) technology and signal processing theories make it feasible to incorporate frame-store memory and sophisticated signal processing capabilities in a television receiver at a reasonable cost. To exploit this new technology in developing future television systems, the research areas of the program focused on a number of issues related to digital television design. As a result of this effort, significant advances have already been made and these advances have been included in the U.S. digital television standard. Specifically, the ATSP group represented MIT in MIT's participation in the Grand Alliance, which consisted of MIT, AT&T, Zenith Electronics Corporation, General Instrument Corporation, David Sarnoff Research Center, Philips Laboratories, and Thomson Consumer Electronics. The Grand Alliance digital television system served as the basis for the U.S. Digital Television (DTV) standard, which was formally adopted by the U.S. Federal Communications Commission in December 1996. The standard imposes substantial constraints on the way the digital television signal is transmitted and received. The standard also leaves considerable room for future improvements through technological advances. Current research focuses on making these future improvements.

In addition to research on issues related to the design of digital television system, the research program also includes research on signal processing for telecommunications applications.

1. Application of Deinterlacing for the Enhancement of Surveillance Video

Sponsor: Advanced Telecommunications Research Program

Project Staff: Brian Heng

As the cost of video technology has fallen, surveillance cameras have become an integral part of a vast number of security systems. However, even with the introduction of progressive video displays, the majority of these systems still use interlaced scanning. The desire to eliminate interlacing artifacts provides motivation for developing high quality algorithms for interlaced to progressive conversion, also known as deinterlacing.

Typically, when criminal investigators view surveillance footage, they only need to analyze a few frames of interest. They often want to view one frame at a time, looking for one good image that can help them identify a suspect or analyze a region of interest. Since the video source is interlaced, this type of frame-by-frame analysis requires some form of deinterlacing. In most surveillance systems, very basic techniques are used for this purpose, resulting in a number of severe visual artifacts and greatly limiting the intelligibility of surveillance video. This research investigates deinterlacing algorithms to determine methods that will improve the quality and intelligibility of video sequences acquired by surveillance systems. Motion adaptive deinterlacing methods have been shown to have the most potential for surveillance video, demonstrating the highest performance both visually and in terms of peak signal-to-noise ratio.

2. Multi-Dimensional Bit Rate Control for Video Communication

Sponsors: Charles Stark Draper Laboratory
Advanced Telecommunications Research Program

Project Staff: Eric Reed

In digital video communications, buffering is required to absorb variations between the source bit rate and the channel transmission rate. Hence, a bit rate control strategy is necessary to maintain the buffer level. In conventional bit rate control, the buffer level is maintained by adapting the quantization stepsize while the frame rate and spatial resolution remain fixed at levels chosen a priori. We investigate a Multi-Dimensional (M-D) bit rate control where the buffer level is maintained by jointly adapting the frame rate, spatial resolution and quantization stepsize. In this approach, the frame rate and spatial resolution are chosen automatically and can adapt to a nonstationary source.

We introduce a fundamental framework to formalize the description of the M-D buffer-constrained allocation problem. Given a set of operating points on a M-D grid to code a nonstationary source in a buffer-constrained environment, we formulate the optimal solution. Our formulation allows a skipped frame to be reconstructed from one coded frame using any temporal interpolation method and is shown to be a generalization of formulations considered in the literature. In the case of intraframe coding, a dynamic programming algorithm is introduced to find the optimal solution. The algorithm allows us to compare operational rate-distortion (R-D) bounds of the M-D and conventional approaches. We also discuss how a solution can be obtained for the case of interframe coding using the optimal dynamic programming algorithm for intraframe coding by making an independent allocation approximation.

We experiment with zero-order hold and global motion-compensated temporal interpolation and illustrate that the M-D approach provides bit rate reductions up to 50 %. We also show that the M-D approach with limited lookahead provides a slightly suboptimal solution that consistently outperforms the conventional approach with full lookahead. While our algorithm is computationally expensive, it can be directly used for nonreal-time applications and can be used to benchmark performance of limited lookahead strategies for real-time applications.

3. Adaptive Format Conversion as Enhancement Information in Scalable Video Coding

Sponsors: Advanced Telecommunications Research Program

Fellowship: INTEL Foundation

Project Staff: Wade Wan

Many video broadcasting applications must provide service to a multicast environment. In this environment, multiple clients require different types of service, also known as service levels, due to variations in their available bandwidth, processing power and memory resources. It is desirable for a video server to provide different resolutions and/or qualities of the same video sequence to satisfy each client type while minimizing the cost of reaching the audience. From the video coding point of view, this cost is the total bandwidth transmitted from the server. Scalable coding techniques are often used to efficiently provide multicast video service and involve transmitting a single independently coded base layer and one or more dependently coded enhancement layers. Clients can decode the base layer bitstream and none, some or all of the enhancement layer bitstreams to obtain video quality commensurate with their available resources. Enhancement layers are dependent on the decoded base layer and the efficient coding of information in enhancement layers has been a topic of substantial research interest. A well-known type of enhancement information is residual coding, which is used in scalable coding schemes such as the spatial scalability profiles in the MPEG-2 and MPEG-4 multimedia standards. There is another type of information that can be transmitted instead of (or in addition to) residual coding. Since the encoder has access to the original sequence, it can utilize adaptive format conversion to generate the enhancement layer and transmit the different format conversion methods as enhancement data. The use of adaptive format conversion for scalable coding has not been studied in detail, but recent research has shown that it can significantly improve video scalability.

This research examines the use of adaptive format conversion information as enhancement data in scalable video coding. The main focus is to determine the conditions where adaptive format conversion can be used instead of or in addition to residual coding to improve video scalability. Simulation results are performed for a wide range of base layer qualities and enhancement bitrates to determine when adaptive format conversion can improve video scalability. Since the parameters needed for adaptive format conversion are small compared to residual coding, adaptive format conversion can provide video scalability at low enhancement layer bitrates that are not possible with residual coding. In addition, adaptive format conversion can also be used in addition to residual coding to improve video scalability at higher enhancement layer bitrates. Many scalable applications may benefit from the use of adaptive format conversion. An application that adaptive format conversion is well-suited for is the migration path for digital television where it can provide immediate video scalability as well as assist future migrations.

4. An Investigation of Methods for HDTV Format Conversions

Sponsors: Advanced Telecommunications Research Program

Fellowship:

Project Staff: Chuohao Yeo

For the last few years, broadcasters have been in transition from the old NTSC standard to the new ATSC digital television standard. A key feature of the new standard is the plethora of supported video formats. While this gives broadcasters greater flexibility in their operations, it has also necessitated format conversion at the transmitter-level and the receiver-level. It is possible for current production equipment to produce video at a resolution of 720x1280 progressively scanned (720p) at 60 frames per second or at a resolution of 1080x1920 interlaced (1080i) at 60 fields per second, but broadcasters can choose to transmit in many other video formats. In addition, a typical consumer HDTV set has only one display format, therefore other video formats that are received must be first converted to its native display format. The ATSC digital television standard also allows for multicasting, or the broadcasting of multiple programs on the same channel. Therefore, broadcasters may be interested in broadcasting programs in a video format that has lower resolution than production formats. While computation time may be an issue in commercial systems, the only criterion used here to evaluate different methods is the output quality. A number of conversion techniques used for de-interlacing and image resizing will be investigated to determine which combination of methods offers the best performance for a small subset of possible format conversions.

Publications

Journal Articles

Published:

E. Reed and F. Dufaux. “Constrained Bit Rate Control for Very Low Bit Rate Streaming Video Applications,” IEEE Transactions on Circuits and Systems for Video Technology, Vol. 11, No. 7, July 2001.

Submitted for Publication:

E. Reed and J. Lim, “Optimal Multi-Dimensional Bit Rate Control for Video Communication,” IEEE Transactions on Image Processing,

Conference Proceedings

Published:

W.K. Wan and J.S. Lim, “Adaptive Format Conversion for Video Scalability at Low Enhancement Bitrates,” *2001 IEEE Midwest Symposium on Circuits and Systems*, Fairborn, Ohio, August 14-17, 2001.

W.K. Wan and J.S. Lim, “Adaptive Format Conversion for Scalable Video Coding,” *Proceedings of SPIE International Symposium on Optical Science and Technology - Applications of Digital Image Processing XXIV*, San Diego, California, July 31-August 3, 2001.

Theses

E. C. Reed, Multi-Dimensional Bit Rate Control for Video Communication, Ph.D. thesis, Department of Electrical Engineering and Computer Science, MIT, 2001

B. A. Heng, Application of Deinterlacing for the Enhancement of Surveillance Video, S. M. thesis, Department of Electrical Engineering and Computer Science, MIT, 2001.