Electronic System Group
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Fields of study: Image processing, Digital Communication
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1. Subject and Aims of Research

Crossing over between the fields of digital image processing and digital communication, in addition to the study of image coding and analysis, we take into account of the tampering and distortion that an image may suffer during transmission (especially in a wireless channel) and develop robust algorithms for image communication.

2. Related Recent Research Topics

(1). Image coding

Edge-enhanced image coding (also called image compression) is addressed. Under a specified rate budget (also called bit budget), an optimal wavelet packet to encode an image is computed in the sense of minimizing the distortion. Closed-form expressions that approximate the rate-distortion (RD) functions of wavelet-decomposed subimages are found. With the aid of these closed-form expressions, the optimal wavelet packet can be determined at low computation cost, where virtually all trial-and-error searches commonly seen in RD optimizations are eliminated. Following the wavelet-packet encoding, which typically does not consume all the rate budget, a greedy edge enhancement algorithm is applied to fully take advantage of the remaining budget and effectively improve the visual quality of the compressed image. As compared to other image compression techniques, experiments show that the proposed scheme produces very good image coding results: high PSNR (peak signal-to-noise ratio) and good edge preservation at the cost of low computation burden for achieving a specified compression ratio.

(2). Digital watermark

Digital watermarking is a technique with which we try to hide a message signal in a multimedia signal for the functions of copyright claim, authentication, device control, or broadcast monitoring, etc. We focus on embedding watermarks into still images. We propose a blind watermarking scheme using orthogonal code spreading in the discrete wavelet transform (DWT) domain of an image. It applies to binary, grayscale, and color images. The watermark itself can be a binary or a grayscale image. For fighting some attacks, including row/column removal, cropping, and image rotation etc., we embed attack-detection messages in the edge lines of the watermarked image. An explicit quantitative relationship regarding the trade-off between the watermark bit error rate (WBER) and the peak signal-to-noise ratio (PSNR) for the proposed scheme is derived. In addition, an unequal error protection (UEP) scheme is proposed to provide different degrees of robustness for watermark bits of different degrees of significance in grayscale watermarks.

(3). Mobile positioning

We address the issue of mobile positioning and tracking given the measured distances between an MS (mobile station) and its nearby base stations (BS's). The measurements can come from the time of arrival (TOA), the time sum of arrival (TSOA), or the time difference of arrival (TDOA). They are in general corrupted with measurement noise and NLOS (non-line-of-sight) error. The NLOS error is the dominant factor that degrades the accuracy of mobile positioning. Assuming the knowledge of its statistic model, however, we propose a scheme to reduce its effect significantly. Regardless of the measurement types (i.e. TOA, TSOA, or TDOA), the proposed scheme computes the MS location in a unified way. Finally, by combining the proposed MS positioning method with Kalman filtering, we propose a scheme to track the movement of the MS.

(4). Error correction in digital communication

Modulation, equalization, and channel coding are jointly considered to achieve highly efficient (in data rate or in bandwidth utilization) and reliable transmission of data. In particular, iterative decoding (inspired by turbo codes) are applied to trellis modulation (resulting in turbo TCM) and equalization (resulting in turbo equalization). EXIT (extrinsic information transfer) charts are used to analyze and predict the bit error rate (or symbol error rate) performance of various cascades of modulation, equalization, and channel coding components. With the application of image transmission (or more generally, multimedia signal) in mind, the technique of unequal error protection is incorporated into the error correction schemes discussed above. The key idea is that more important bits should be protected with more powerful error correction setup (within the power and bandwidth budget, of course). Additionally, the technique of network coding is integrated with error control coding/modulation to reduce the data transmission delay in a communication network.

3. Selected Publications and Projects

Publication:

(1). C. T. Hung and K. T. Lay, “Data rate maximization under joint energy and DOS constraints in multichannel communications,” IEICE Trans. Commun., Vol. E85-B, No. 11, pp. 2369-2378, Nov. 2002.

(2). J. H. Chen and K. T. Lay, “Finite field wavelet spread signature CDMA in a multipath fading channel,” IEICE Trans. Commun., Vol. E86-B, No. 1, pp. 122-131, Jan. 2003.

(3). M. C. Cheng and K. T. Lay , “An Embedding Scheme for Binary and Grayscale Watermarks by Spectrum Spreading and Its Performance Analysis,” IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences, Vol. E90-A, No. 3, pp. 670-681, March 2007.

(4) W. K. Chao and K. T. Lay, ”Mobile Positioning and Tracking Based on TOA/TSOA/TDOA/AOA with NLOS-Reduced Distance Measurements,” IEICE Trans. Commun., Vol. E90-B, No. 12, pp. 3643-3653, Dec. 2007.

Projects:

(1). “Robust and Secure Watermark Embedding in Wavelet-Coded Image,” 2003. Project number : NSC 91-2213-E-011-007

(2). “Trellis-Based Source-Channel Coding of Watermarked Images,” 2004. Project number : NSC 92-2213-E-011-086

(3) “Reliability-Bearing Embedding and Extraction of Grayscale Watermarks by Error Control Coding Capable of Soft Decision,” 2005. Project number: NSC 93-2213-E-011-075

(4) “HAS-Matched Robust Audio Watermarking with Spectrum Spreading and Attack Characterization in the Transform Domain,” 2006. Project number: NSC 94-2213-E-011-022

(5) “Positioning and Tracking of Mobile Stations in Wireless Cellular Networks,” 2007. Project number: NSC 95-2221-E-011-027

(6) “Transmission of Multimedia Signals with Dynamic Data Transmission Configurations in Wireless Channels,” 2008. Project number: NSC 96-2221-E-011-011