CIS 751 Multimedia Computer Systems

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Monday 6:00pm-8:05pm

232NE

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COURSE DESCRIPTION

With the advent of digital technologies, and the explosive use of the World Wide Web (WWW), multimedia data now plays an important role in a number of fields including medicine, commerce, education, journalism, and entertainment.

In this course, we will focus on five research areas for multimedia content: Encryption, watermarking, compression, quality measurement, and retrieval.

- In secure multimedia content distribution, the audio/visual stream is compressed, packetized, and encrypted. The level of security provided by encryption depends not only on cipher strength and key length but also on implementation details. Symmetric key ciphers such as DES are commonly used for the protection of multimedia content. The protection of the decryption keys is usually defined privately by conditional access (CA) or digital rights management (DRM) systems. A CA system allows access to services based on payment or other requirements such as identification, authorization, authentication, and registration. Using satellite, terrestrial or cable transmissions, the service providers deliver different types of multimedia content ranging from free access programs to services such as PayTV, Pay-Per-View and Video-on-Demand. Digital Rights Management (DRM) refers to the protection, distribution, modification and enforcement of the rights associated with the use of digital content. In general, the primary responsibilities of a DRM system are (1) secure delivery of content to users, (2) prevention of unauthorized access, (3) enforcement of usage rules, and (4) monitoring of the use of content. Although such systems can, in principle, be deployed for any type of distribution media, the present discussions weigh more heavily on the Internet. DRM systems use cryptography for security related functions, which generally include secure delivery of content, secure delivery of decryption keys, integrity of usage rights, and client authentication. The traditional mechanism to support multicast communications is IP multicast. It uses the notion of a group of members identified with a given group address. When a sender sends a message to this group address, the network uses a multicast routing protocol to optimally replicate the message and forward copies to group members located throughout the network. MSEC is an IETF working group whose purpose is to standardize protocols for securing group communication over the global internet.

- A watermark can be embedded into a multimedia element such as image, audio or video. This embedded data can later be extracted from, or detected in, the multimedia for security purposes. A watermarking algorithm consists of the watermark structure, an embedding algorithm, and an extraction, or a detection, algorithm. In multimedia applications, embedded watermarks should be invisible, robust, and have a high capacity. Invisibility refers to the degree of distortion introduced by the watermark and its affect on the viewers or listeners. Robustness is the resistance of an embedded watermark against intentional attacks and normal A/V processes such as noise, filtering (blurring, sharpening, etc.), resampling, scaling, rotation, cropping and lossy compression. Capacity is the amount of data that can be represented by an embedded watermark. Typical uses of watermarks include identification of the origin of content, tracing illegally distributed copies, and disabling unauthorized access to content. Several criteria can be used to classify watermarking systems. Three of such criteria are the type of domain (pixel or transform), the type of watermark (pseudo random number sequence or visual watermark), and the type of information needed in the detection or extraction process (original signal and/or secret keys). In general, the systems that embed the watermark in the pixel domain are less robust to image manipulations, and semi-blind and blind systems are more prone to false positives (detecting the watermark in an unmarked image) and false negatives (not detecting the watermark in a marked image). It should be noted that non-blind schemes are appropriate for some of the watermarking applications, and semi-blind or blind schemes for the others. For example, if an owner needs to prove the ownership of an image, the watermark detector or extractor can be used in a special laboratory environment to compare the original unmarked image with the marked one. However, if the watermark is intended for copy control purposes, "compliant" consumer electronics devices that play or record multimedia content will be required to contain a watermark detector/extractor. Hence, the cost of implementation will highly depend on the application, and may vary considerably from one application to another.

- Compression refers to the process of reducing the amount of data required to represent a given quantity of information. Every day, an enormous amount of digital information is stored, processed and transmitted. At the present time, libraries, museums, film studios, and governments are converting data into digital form. For example, the entire catalog of the Library of Congress (the world's largest library) is available electronically. As much of the on-line information is consisted of multimedia elements such as images, video and audio files, the storage and communications requirements are immense! Compression schemes can be classified into two groups: lossless and lossy. If compression and decompression induce no information loss, the scheme is lossless. These schemes are particularly useful for archival purposes (e.g., the storage of legal documents). Three examples of lossless compression schemes are Huffman coding, arithmetic coding, and Lempel-Ziv-Welch (LZW) coding. Lossy compression has a number of important applications such as broadcasting digital television and videoconferencing. JPEG and JPEG 2000 are two standardized lossy compression schemes for images. JPEG is based on Discrete Cosine Transform (DCT), and JPEG 2000 is based on Discrete Wavelet Transform (DWT). The basic steps in lossy image compression are (1) application of the transform, (2) quantization, and entropy coding. A major standard for video is MPEG 2 which also removes temporal redundancy, i.e., the redundancy between the video frames. MPEG 4 is a more recent standard that builds on the proven success of three fields: Digital television; Interactive graphics applications (synthetic content); Interactive multimedia (World Wide Web, distribution of and access to content).

- Image quality measurement is one of the most challenging problems in image processing. A tool is needed to measure the distortion caused by compression, watermarking and other sources of noise. Subjective evaluation is cumbersome as the human observers can be influenced by several critical factors such as the environmental conditions, motivation and mood. The objective measures include bivariate measures such as the Mean Squared Error (MSE) and L_p-norm, measures mimicking the human visual system (HVS), and a few graphical measures. The most common objective evaluation tool, the MSE, is very unreliable, resulting in poor correlation with the HVS. An ideal image quality measure should be able to describe the amount of distortion, the type of distortion, and the distribution of error. Such a measure is expected to provide accurate predictions of quality not only at distortion ranges near the visual threshold but also when distortions are significantly above the visual threshold. Undoubtedly, there is a need for an objective measure that provides more information than a single numerical value. Image quality measures can be classified into two groups: full-reference and no-reference. Measures that require both the original (reference) image and the distorted image are called "full-reference" methods while those that do not require the original image are called "no-reference" methods.

- The increasing popularity of digital images in many applications has created a need to organize, store, and retrieve images from databases. Traditional methods of image indexing based on classification schemes or keywords have severe limitations. Content based image retrieval (CBIR) is a new research area to develop techniques for retrieving images based on automatic derivation of features extracted from them. A fundamental difference between textual and visual information is the nature of the retrieval process. The retrieval of textual information is based on discovering semantic or syntactic similarity between textual entities. Visual information retrieval is concerned with discovering perceptual similarity. The concept of perceptual similarity is usually made clear by examining the types of queries that users may use when retrieving images from an image database. Although there is insufficient evidence to categorize the user queries, it has been found useful to classify image queries into three levels of increasing complexity: Level 1 comprises retrieval by primitive features such as color, texture, and shape. This type of query is objective, and composed of features derived from images using image processing algorithms, not requiring any external knowledge base. Level 2 comprises retrieval by derived features, involving some degree of logical inference about the identity of the objects in the image. To answer queries at this level, an external knowledge base is normally required. Level 3 comprises of retrieval by abstract attributes, and necessitates a significant amount of higher level reasoning about the meaning and purpose of the objects or scenes depicted. As the link between image content and abstract concepts requires complex reasoning and subjective judgment, systems based on this type of visual processing will incorporate humans for guidance. Recent research has more focus on both the statistical features extracted from images and the text associated with images.

RECOMMENDED TEXTBOOKS

1. B. Schneier, Applied Cryptography, John Wiley and Sons, Inc, 1996.
2. A. J. Menezes, P. C. van Oorschot, and S. A. Vanstone, Handbook of Applied Cryptography, CRC Press, 1997.
3. I. J. Cox, M. L. Miller and J. A. Bloom, Digital Watermarking, Morgan Kaufmann Publishers, 2001.
4. F. Halsall, Multimedia Communications, Addison-Wesley, 2001.
5. K. R. Rao, Zoran S. Bojkovic, Dragorad A. Milovanovic, Multimedia Communication Systems, Prentice Hall, 2002.
6. R. Steinmetz, K. Nahrstedt, Multimedia Fundamentals, Prentice Hall, 2002.
7. M. Arnold, M. Schmucker, S. D. Wolthusen, Techniques and Applications of Digital Watermarking and Content Protection, Artech House, 2003.
8. Mark S Drew, Ze-Nian Li, Fundamentals of Multimedia, Prentice Hall, 2004.

REQUIRED PAPERS

Encryption

1. A. M. Eskicioglu, "Protecting Intellectual Property in Digital Multimedia Networks," IEEE Computer, Special Issue on Piracy and Privacy, pp. 39-45, July 2003.
2. A. M. Eskicioglu, J. Town, E. J. Delp, "Security of Digital Entertainment Content from Creation to Consumption," Signal Processing: Image Communication, Special Issue on Image Security, Vol. 18, Issue 4, pp. 237-262, April 2003.
3. C. K. Wong, M. G. Gouda and S. S. Lam, "Secure Group Communications Using Key Graphs," IEEE/ACM Transactions on Networking, Vol. 8, No.1, February 2000.

Watermarking

4. I. J. Cox, J. Kilian, T. Leighton and T. Shamoon, "Secure Spread Spectrum Watermarking for Multimedia," IEEE Transactions on Image Processing, 6(12), pp. 1673-1687, 1997.
5. R. Liu and T. Tan, "A SVD-Based Watermarking Scheme for Protecting Rightful Ownership," IEEE Transactions on Multimedia, 4(1), pp.121-128, March 2002.
6. R. Dugad, K. Ratakonda, and N. Ahuja, "A New Wavelet-Based Scheme for Watermarking Images," *Proceedings of 1998 International Conference on Image Processing (ICIP 1998)*, Vol. 2, Chicago, IL, October 4-7, 1998, pp. 419-423.
7. R. Caldelli, M. Barni, F. Bartolini, A. Piva, "Geometric-Invariant Robust Watermarking through Constellation Matching in the Frequency Domain," *Proceedings of the 2000 International Conference on Image Processing (ICIP 2000)*, Vancouver, BC, Canada, September 10-13, 2000, Vol. II, Vancouver, Canada, September 10-13, 2000, pp. 65-68.

8. P. Tao and A. M. Eskicioglu, “A Robust Multiple Watermarking Scheme in the Discrete Wavelet Transform Domain,” *Optics East 2004 Symposium, Internet Multimedia Management Systems V Conference*, Philadelphia, PA, October 25-28, 2004.

9. J. Kusyk and A. M. Eskicioglu, “A Semi-Blind Logo Watermarking Scheme for Color Images by Comparison and Modification of DFT Coefficients,” Optics East 2005 Symposium, Internet Multimedia Management Systems VI Conference, Boston, MA, October 23-26, 2005.

10. E. Elbasi and A. M. Eskicioglu, “A DWT-based Robust Semi-Blind Image Watermarking Algorithm Using Two Bands,” IS&T/SPIE’s 18th Annual Symposium on Electronic Imaging, Security, Steganography, and Watermarking of Multimedia Contents VIII Conference San Jose, CA, January 15–19, 2006.

Image Quality Measurement

11. A. M. Eskicioglu and P. S. Fisher, “Image Quality Measures and Their Performance,” IEEE Transactions on Communications, 43(12), pp. 2959-2965, December 1995.

12. Z. Wang and A. C. Bovik, “A Universal Image Quality Index,” IEEE Signal Processing Letters, 9(3), pp. 81-84, March 2002.

13. Z. Wang, A. C. Bovik, H. R. Sheikh, and E. P. Simoncelli, “Image Quality Assessment: from Error Measurement to Structural Similarity,” IEEE Transactions on Image Processing Vol. 13. No. 4, April 2004.

14. A. Shnayderman, A. Gusev, and A. M. Eskicioglu, “An SVD-Based Gray-Scale Image Quality Measure for Local and Global Assessment,” IEEE Transactions on Image Processing, 2006.

15. Z. Wang, H. R. Sheikh and A. C. Bovik, “No-Reference Perceptual Quality Assessment of JPEG Compressed Images,” Proceedings of IEEE 2002 International Conference on Image Processing Rochester, NY, September 22-25, 2002.

Image Retrieval

17. Y. Rui, T. S. Huang and S.-F. Chang, “Image Retrieval: Current Techniques, Promising Directions and Open Issues,” Journal of Visual Communication and Image Representation, Vol. 10, pp. 39-62, March 1999.

18. J. P. Eakins, “Retrieval of Still Images by Content,” European Summer School in Information Retrieval 2000, Villa Monastero, Varenna, Italy, September 10-16, 2000.

19. A.W. M. Smeulders, M. Worring, S. Santini, A. Gupta, R. Jain, “Content-Based Image Retrieval at the End of the Early Years,” IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 22, No. 12, December 2000.

RELEVANT PUBLICATIONS

Journals

1. IEEE Transactions on Communications
2. IEEE Transactions on Multimedia
3. IEEE Transactions on Image Processing
4. IEEE Transactions on Signal Processing
5. Proceedings of the IEEE
6. ACM Multimedia Systems Journal
7. Signal Processing Journal
8. Signal Processing: Image Communication Journal
9. Journal of Electronic Imaging
10. Computers and Graphics Journal

Professional Magazines

1. IEEE Multimedia Magazine
2. IEEE Signal Processing Magazine
3. IEEE Communications Magazine
4. IEEE Computer Magazine

International Conferences

1. IEEE International Conference on Image Processing (ICIP)
2. IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP)
3. IEEE International Conference on Multimedia and Expo (ICME)
4. ACM Multimedia Conference (ACM MM)
5. IS&T/SPIE Symposium on Electronic Imaging (EI)
6. European Signal Processing Conference (EUSIPCO)

GRADING

Midterm Exam (Take-Home)	30%
Final Exam	40%
Paper Presentation (Optional)	15%
Attendance	15%

Each student’s final grade will be computed using the above weights and a 100-point scale. The corresponding letter grade, however, will be based on a curve.

EXAMS

The exams will test the students' level of understanding of the terminology, concepts and other technical details discussed throughout the semester. The final exam is closed book/notes exams, and will be taken during regular class time. The students are expected to carefully read all the assigned papers and additional background material. If a student misses an exam without a medical report from a doctor, he/she will receive a zero for that exam. No excuses other than a doctor's report will be accepted.

PAPER PRESENTATION

Each student will present one of the assigned papers using PowerPoint slides. This will contribute up to 15 points to the final grade. The presentation will summarize the paper, focusing on the important findings of the authors' research. Each presentation will be graded based on the quality of the summary, and the student's knowledge of the material discussed in the paper.

ATTENDANCE

Attendance is very important for this class. If a student misses a class, he/she will lose 0.714 points. It is expected that the students will actively participate in the classroom by taking notes, asking questions, and expressing opinion. If a student anticipates that he/she will have a poor performance in the course, the instructor should be contacted as soon as possible to discuss possible remedies for improvement. The office hours are allocated to extend the time spent with the students for a discussion of all course-related academic problems. The best communication with the instructor can be established during the lectures and office hours.