

Statement of Research

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A new economy based on information in digital form has emerged. People create, sell, and interact with multimedia content. The Internet provides a ubiquitous infrastructure for e-commerce; however, it does not provide enough protection for its participants. Lacking adequate protection mechanisms, content providers are reluctant to distribute their digital contents, because they can be easily re-distributed; content receivers are skeptical about the reality and integrity of content. Current technology in network security protects contents during one stage of transmission. But, it cannot protect multimedia data through multiple stages of transmission entities, including human beings and machines. These concerns have hindered the universal acceptance of digital multimedia. At the same time, they also stimulate a new research field: *multimedia security*.

My research interests are developing algorithms for various multimedia security applications and designing protocols for multimedia security systems. In general, multimedia security includes five major applications: *copyright protection*, *authentication*, *fingerprinting*, *info hiding*, and *hidden annotation*. All of them are based on *digital watermarking*, a technique that embeds extra information in multimedia data, while some objectives can be realized by *robust digital signature*. Different application drives different requirements in robustness, amount of embedded information, security, and imperceptibility.

Previous development of multimedia security techniques has shown promising results, and there are still a lot of open research issues. Here, I describe the current research issues, my past contributions, and my research plans in each area.

Copyright protection

Description: Copyright protection is utilized by embedding the owner identification into the multimedia content. This embedded information (*i.e.*, watermark) has to be robust against attacks. Current watermarking techniques can survive various manipulations, with the presence of the source image. Recently, researchers are developing public watermarking techniques that do not need the source data. They are also designing techniques for other types of multimedia such as video, graph, audio, and document.

My past contribution: Designed the first public watermarking scheme surviving print-and-scan process. I was the first researcher to model the distortion of digital images after print-and-scan, and the primary contributor to the design of a novel public watermarking method based on feature vector shaping.

My research plan:

- **Public Watermarking for Multimedia Copyright Protection:** This project includes (1) modeling of multimedia signal distortion after various D/A transcoding processes and compression schemes, and (2) designing public watermarking schemes for various multimedia format based on the distortion models, feature vector shaping, and/or new developments.

Multimedia authentication

Description: Multimedia authentication techniques are used to verify the integrity of data, the alleged source of data, and/or the reality of data. They are based on the *semi-fragile watermarks* or *robust digital signature*. The state-of-the-art image authentication techniques (developed by me and Prof. Chang) can detect malicious manipulations, accept lossy compressions, and even roughly recover the changed area. The future directions in multimedia authentication are to develop techniques for other types of multimedia, and to accept different kinds of manipulations, *e.g.*, D/A transcoding process.

My past contribution: Designed the first semi-fragile watermarking/robust digital signature authentication method. It is based on my discovery of two invariant theorems of JPEG/MPEG that are used for generating and embedding authentication bits. One theorem shows a high capacity information hiding technique surviving standard compression. Hence, recovery information can be embedded in the image/video. My other contributions include: (1) the first development of video authentication techniques, (2) the first discussion and problem specification in the field of multimedia authentication, and (3) the classification and collection of multimedia authentication archives.

My research plans:

- **Content-based Multimedia Authentication:** This project is to develop multimedia authentication methods based on the content analysis techniques. My focuses are on the mechanism of authenticating multimedia data using different representation layers, and the stability of automatic feature extraction.

- **Document Authentication:** Documents are a hybrid of text, pictures, and graphs. This project includes two directions: (1) authentication of digital documents after they are printed-and-scanned, and (2) authentication of paper format documents after they are scanned-and-printed and photocopied. The first direction is to develop watermarking/ digital signature techniques for the continuous toned images, indexed color graphs, and text. The second direction is to develop half-toning techniques that can hide information in the bi-level toned documents.
- **Audio Authentication:** This project is to study the state-of-the-art speech and speaker recognition techniques, and to embed the speaker (or his/her vocal characteristics) and speech content in the audio signal. This research also includes the development of audio watermarking techniques surviving lossy compression.
- **Image/Video/Graph Authentication:** This project will focus on developing authentication techniques to accept JPEG-2000 compression and general image/video processing operations, and reject malicious manipulations.

Fingerprinting

Description: This application embeds multiple receiver identifications as tracing evidence in distribution. The difficulties are to design co-existing watermarks and the cooperation with the web server providers.

My research plan:

- **Fingerprinting on Multimedia data:** This project includes two parts. The first part is to design multiple watermarking techniques. It may be derived from the existing TDMA, FDMA, and CDMA methods. The second part is to develop software for the web server and to design protocols for tracing illegal distribution.

Information Hiding

Description: Information hiding utilizes the multimedia data as a media to transmit information, which can be the objective information (as used in military) or value-added information (such as the personal data of a picture). The considerations and difficulties in information hiding are similar to the semi-fragile watermark: robustness, large amount of data, and imperceptibility.

My past contribution: I developed a high capacity information hiding technique surviving standard compression. This method embeds about 3-10 times more information bits than previous methods.

My research plan:

- **Information Hiding on Multimedia data:** This project will focus on developing high capacity information hiding techniques in the digital domain, and developing information hiding methods in the traditional domain such as printed documents or magnetic audio/video tapes.

Hidden Annotation

Description: embeds watermarks as control flags to the multimedia data, such as copy control, read-only indication, etc. Recently, several commercial groups have developed watermarking techniques for DVD. Efforts on similar techniques for MP3 music are underway. Further developments will focus more on the control of document/images.

Infrastructure for multimedia security systems

Description: In addition to the multimedia authentication techniques, infrastructure of multimedia security systems is an important issue still under investigation. Its construction needs deliberate and reliable protocols as well as software/hardware devices. Currently, only DVD and MP3 issues have been discussed, while an MPEG-4 watermarking working group has just begun to organize.

My research plans:

- **Multimedia Security Infrastructure:** This project includes several parts. The first part is to develop authentication and copyright protection protocols in cooperation with the Public Key Infrastructure (PKI) used for network security. The second part is to design protocols for specific applications such as MPEG-4 video or JPEG-2000 images/documents. The third part is to develop compatible watermarking methods for hidden annotation.

I have been working on the multimedia security issues, doing pioneering work in multimedia authentication and public watermarking, since 1996. My past contributions have demonstrated my capability of doing first-rate research in this field. With these records, I believe I can go on to realize my research goals with your exceptional students and research environment. I sincerely hope to attain an assistant professor position and make contribution to your esteemed institute.

Statement of Teaching

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I plan to teach these three courses. These courses provide foundations to students who are interested in multimedia applications and network security issues. Besides, I can teach other courses such as: *probability and stochastic process, numerical linear algebra, signal and system, digital signal/ image/video processing, communication, computer communication network, computer vision, information theory, etc.*

Multimedia Representation

Course objectives: This course provides theoretical foundation and practical experience in modern techniques of digitally representing multimedia information. It presents an in-depth perspective of media representation theory, which helps students to establish background knowledge in designing multimedia applications. Students can select substantial programming projects on multimedia transcoding or compressed-domain processing.

Topics:

Multimedia devices and representation methods: Telephone, Radio, TV, CD, VHS, Internet	3 hours
Sampling and coding theory; various kinds of multimedia coding (entropy, quantization, subband, transform, and vector coding)	12 hours
Audio characteristics and formats: LPC, MP3	6 hours
Image characteristics and formats: PPM, TIFF, BMP, GIF, JPEG, JPEG 2000	6 hours
Document characteristics and formats: PS, PDF, Dejavu, JBIG, G3/G4 facsimile, half-toning	6 hours
Video characteristics, formats, and networking protocols: H.261/3, MPEG-1/2/4, QuickTime	10 hours

Network Security

Course objectives: This course provides the necessary foundations for network security including cryptography, encryption techniques, design of secure systems and protocols, and enhancement of existing protocols. It provides real-life projects such as designing the platforms for e-commerce.

Topics:

Issues of network security	3 hours
Cryptography; secret key algorithms; hashes and message digests; public key algorithms	15 hours
Authentication systems; authentication of people; authentication of multimedia data	7 hours
Security handshake pitfalls; secret key based authentication systems; Kerberos V4, V5.	6 hours
IP security and electronic mail security	6 hours
Web security and SSL	6 hours

Multimedia Information Systems

Course objectives: This course presents and discusses several advanced topics in the area of multimedia processing and information systems. It provides students the necessary theoretical foundation and perspective on the state-of-the-art development in multimedia applications.

Topics:

Overview, system architecture, multimedia representation	4 hours
Multimedia feature extraction, pattern recognition, and content analysis	9 hours
Multimedia editing, indexing, storage, and retrieval, MPEG-7	9 hours
Image/video object segmentation and object-based applications, MPEG-4, Human-Computer Interface	9 hours
Multimedia watermarking, info hiding, and security	12 hours