Chapter 11

Conclusions and Perspectives

This thesis presents multiple aspects of data hiding with both analytic study and experimental results. We have shown that multimedia data hiding can be used for various applications, including ownership protection, alteration detection, access/copy control, annotation, and conveying other side information. In addition to the design issues, we discussed attacks on watermarking algorithms with a goal of identifying weaknesses and limitations of existing design/framework as well as proposing improvements.

While we have discussed many advantages of data hiding and enumerated a number of possible applications, it is necessary in practice to justify case by case the need of data hiding versus the alternatives such as putting side information in the user data field. We feel it important to understand that in spite of the interesting intellectual challenge and the current popularity of data hiding in the research community, engineering practice would always favor simplicity, efficiency, and effectiveness than simply following a new fashion. On the other hand, currently identified challenges, weaknesses, as well as limitations are not yet sufficient in drawing conclusion on the usefulness of digital watermarking and multimedia data hiding. The field is still young and involves various disciplines such as signal processing, computer security,

psychology and economics/business. Paradigms and underlying theories are either just being set or to be set. Therefore, objective and multi-disciplinary approaches would continue to be necessities for studying various aspects of multimedia data hiding.

Despite of the differences, data hiding (stegnography) and cryptography are tightly connected. Many ideas of cryptography have found to be very useful in such existing data hiding works as tampering detection. As for the future research, it would be fruitful to undertake a more general investigation regarding what new value can be offered by combining stegnography and cryptography, and how to make use of this combination to complement the weaknesses or limitations of each one individually. This study would lead to a basis for designing practical media security systems, and to solutions of the *Digital Rights Management* (DRM) for digital multimedia data.

In addition, regarding the gap between the highly simplified channel models and the real-world scenarios in today's data hiding research, a rigorous analysis of the capacity versus robustness of data hiding in a realistic setting and incorporating perceptual models (rather than using a simplified assumption such as Gaussian distribution) is worthwhile to pursue. Without neglecting the intellectual contribution by capacity study toward the understanding of data hiding, it is expected that any fundamental study regarding embedding capacity could ultimately throw light to designing or improving practical data hiding systems for a variety of applications.

Besides the classic use in ownership protection and copy/access control, we have demonstrated that data hiding can be a useful tool to send side information in video communication. This direction is rather new and can be further explored for applications other than those discussed in this thesis. Along with this pursuit, research need to be performed toward the integration of error resilience, transcoding, network

condition measurement, dynamic resource allocation, and admission control in a multimedia communication system, aiming at studying the relations and the interplay of various modules that were generally addressed individually. This interdisciplinary study with theories and practice in network communication, signal processing, neural network, optimization and control systems can lead to better understanding and deployment of multimedia communication.