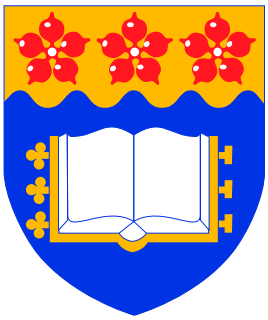
2010

# Scalable watermarking for images

Angela Piper
*University of Wollongong*, apiper@uow.edu.au



# Scalable Watermarking for Images

A thesis submitted in fulfilment of the
requirements for the award of the degree

**Doctor of Philosophy**

from

University of Wollongong

by

**Angela Piper**

School of Computer Science and Software Engineering
Faculty of Informatics
March 2010

*For my grandparents,*
*who encouraged my interest in all things.*

# Certification

I, Angela Piper, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Computer Science and Software Engineering, Faculty of Informatics, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged below. The document has not been submitted for qualifications at any other academic institution.

Angela Piper
September 2, 2010

# Abstract

Digital watermarking allows the embedding of a signal in multimedia content without affecting its quality or usability. This signal can then be used to identify or confirm the creator or owner, track or prevent unauthorised distribution or verify the integrity of the content, and for a variety of other purposes; making digital watermarking a useful component in the protection of digital multimedia content.

With growing demand for both high quality and mobile content, scalable compression has become an increasingly important tool in the distribution of digital content online. It allows content to be scaled to suit a wide range of users and device capabilities in changing network conditions. In particular, resolution scalable compression allows adaptation to different display resolutions, and quality scalable compression caters for to different bandwidths.

However, for low end devices and low bandwidth connections, the scaling process typically alters the content beyond what a traditional digital watermark is designed to handle. Thus the field of scalable watermarking has emerged to provide digital watermarking algorithms that are suitable for scalably compressed content.

In this thesis, resolution and quality scalable watermarking is examined in the context of images, with the aim of developing a watermarking algorithm that is both resolution and quality scalable.

Precisely what it meant for a watermarking algorithm to be *scalable* had not previously been formally defined, and informal descriptions would often focus on a certain desirable property for a scalable watermarking algorithm to the exclusion of some other important property. A definition of a scalable watermarking algorithm is proposed, which considers watermark scalability in terms of two properties that describe the ability of the watermark to both survive high levels of scalable compression and yet still adequately protect all layers of the image. Quantitative measures of these properties are also constructed, to allow the scalability of a watermarking algorithm to be evaluated according to the proposed definition.

Although scalable image compression allowed two types of scalability – resolution and quality – prior to the work in this thesis, scalable watermarking algorithms typically

provided only one type of scalability or the other (or provided both with the provision that one of the two types be selected at the time of embedding). The problem of creating a single watermarking algorithm that provides both resolution and quality scalability, simultaneously, is considered, using JPEG2000 as a representative scalable compression algorithm.

A non-blind spread spectrum based watermarking algorithm is developed, by combining resolution scalable coefficient selection with a human visual system based embedding strength. The resulting watermark provides both detectability and graceful improvement, allowing resolution scaling to $\frac{1}{256}$th the original image area, and quality scaling to $\frac{1}{100}$th the original file size, exceeding the resolution and quality scalability reported for other scalable image watermarking algorithms.

A blind, quantization based algorithm is also developed, that provides detectability and graceful improvement for resolution scaling to $\frac{1}{1024}$th the area and quality scaling to $\frac{1}{100}$th the size, and additionally maintains an exact match between the candidate and extracted watermarks under scaling. This algorithm is adapted for image authentication, and is sensitive to small changes, including Holliman-Memon and collage attacks, but remains undamaged by JPEG2000 scaling. Previous image authentication watermarks that both tolerate scaling and are secure against Holliman-Memon and collage attacks typically offer only one type of scalability and do not provide graceful improvement.

# Acknowledgements

Despite the nature of PhD candidature as a largely solitary process, I find myself with many people to thank[1].

Firstly I would like to thank my supervisor, Reihaneh Safavi-Naini, for all her time and effort, and for teaching me the importance of hard work and determination, in research and in life generally. I would also like to thank both Alfred Mertins, my co-supervisor during the early stages of candidature, and Philip Ogunbona, my co-supervisor during the later stages, for their technical advice and for helping me to improve my research.

I have benefited greatly from the advice of Pam Davy and David Griffiths, who generously provided their time and expertise to further my understanding of statistical analysis. This thesis would be poorer were it not for their assistance.

This thesis has also been enhanced by the efforts of Ian Piper and Gary Watson. I am grateful to them both for proofreading my thesis, and for acting as though that task were not the tedious and unpleasant chore that I am sure it must have been.

I very much appreciate the assistance of the Smart Internet Technology CRC, not only for the partial funding of my research, but for providing opportunities to converse with a variety of PhD students and other researchers from many disciplines, whom I would not otherwise have encountered.

So many staff in the Faculty of Informatics offered their encouragement, support or assistance. I wish there were room to acknowledge more than Gene Awyzio, Bob Brown, Peter Castle, Wanqing Li, Luke McAven, Yi Mu, Jennifer Seberry and Minjie Zhang from the academic staff; Michael Milway and David Wilson from the IT support staff; and Donna Edwards, Sonia Jennings, Anne Nealon, and Karen Williams from the administrative staff.

I am also grateful to Wily Susilo, in his role as Co-Director of the Center for Computer and Information Security Research, for providing part of the funding that allowed me to visit my supervisor in Calgary. This visit was enhanced immeasurably by the kind hospitality of Sirpa Torrence and her family, who provided me with a second home for the

[1] This provides me with a sudden sympathy with anyone who has ever felt compelled to write an overlong acceptance speech. I comfort myself with the thought that should my own audience become weary, they need only turn the page

duration of my stay; and by the students and other researchers at iCORE, who welcomed me into their lab.

To my many labmates in Wollongong, especially Gareth Brisbane, Jeffrey Horton, Wenming Lu, Mohammad Reyhanitabar, Martin Surminen, Siamak Shahandashti, Pairat Thorncharoensri, Dongvu Tonien, Takeyuki Uehara, and Rungrat Wiangsripanawan, thank you. I have enjoyed our discussions, and my time as a PhD student has been greatly enriched by sharing a lab with you. (In addition, my heartfelt gratitude to the unknown labmate whose abandoned heater I inherited.)

Thank you to my friends, for your patience at my neglect, your understanding when I couldn't stop talking in maths or computerese, and for your support, your encouragement and your excitement on my behalf. I am lucky to have you. Particular thanks to Mathew Baddams, Jennifer Cowland and Suzanne Thompson, who have been there for me to rely on since I began this.

Thank you to my cousin Emily Milburn and her husband Nathan, for convincing me to take a break and visit you in Melbourne right when I needed it, and for looking after me so well. Also to my friends Kieron Briggs, Steven Kreusser and Emma Lord for making that break even better.

Indeed, thank you to all of my family. Especially to my aunt and uncle, Julie and Clark Hodgson, for their love and support always but also for doing all the things that I couldn't do to help my grandparents during these past years.

Finally, thank you to my parents, Ian and Sandra Piper, for everything and everything.

# Publications

The following is a list of the jounral articles and peer reviwed conference papers that have been presented during the course of the work conducted as part of this thesis.

A. Piper and R. Safavi-Naini. "How to compare image watermarking algorithms," Y. Q. Shi, Ed., *Trans. Data Hiding and Multimedia Security IV*, pp. 1–28, ser. Lecture Notes in Computer Science, vol. 5510, Springer Berlin/Heidelburg, 2009.

A. Piper, R. Safavi-Naini, and A. Mertins. "Resolution and quality scalable spread spectrum image watermarking," in A. M. Eskicioglu, J. J. Fridrich and J. Dittmann, Eds., *Proc. 7th ACM Workshop on Multimedia & Security (MM&Sec'05), New York, NY, USA, Aug. 1-2*, ACM Press, 2005. pp. 79–90.

A. Piper. "Refined threshold adaptation for scalable watermarking," (best student paper award) [Abstract], in J. Fulcher and K. Ward, Eds., *SITACS Research Student Conference Abstracts.* School of Information Technology and Computer Science, University of Wollongong, Oct. 27, 2004.

A. Piper, R. Safavi-Naini, and A. Mertins. "Coefficient selection methods for scalable spread spectrum watermarking," in T. Kalker, I. J. Cox, Y. M. Ro, Eds., *Proc. Digital Watermarking: Second Intl. Workshop (IWDW), Seoul, Korea, Oct. 20–22*, ser. Lecture Notes in Computer Science, vol. 2939. Springer Berlin/Heidelburg, 2003, pp. 235–246.

# Contents

# List of Tables

# List of Figures