Analysis and Evaluation of Visual Information Systems Performance

Michael Grubinger

This thesis is presented in fulfilment of
the requirements for the degree of
Doctor of Philosophy

School of Computer Science and Mathematics
Faculty of Health, Engineering and Science
Victoria University

April 2007

Abstract

This dissertation investigates the system-centred evaluation of visual information retrieval from generic photographic collections.

The development of visual information retrieval systems has long been hindered by the lack of standardised benchmarks. Researchers have proposed numerous systems and techniques, and although different systems clearly have their particular strength, there is a tendency by researchers to use different means of showing retrieval performance to highlight the own algorithm's benefits. For the field of visual information search to advance, however, objective evaluation to identify, compare and validate the strengths and merits of different systems is therefore essential. Benchmarks to carry out such evaluation have recently been developed, and evaluation events have also been organised for several domains. Yet, no efforts have considered the evaluation of retrieval from generic photographic collections (*i.e.* containing everyday real-world photographs akin to those that can frequently be found in private photographic collections as well, *e.g.* pictures of holidays and events).

We therefore first analyse a multitude of variables and factors with respect to the performance and requirements of visual information systems, and we then design and implement the framework and resources necessary to carry out such an evaluation. These resources include: a parametric image collection, representative search requests, relevance assessments and a set of performance measures. In addition, we organise the first evaluation event for retrieval from generic photographic collections and report on its realisation. Finally, we present an analysis and the evaluation of the participating retrieval systems as well as of the evaluation event itself.

Filling this particular gap by making possible a systematic calibration and comparison of system performance for retrieval from generic photographic collections constitutes the main scientific contribution of this research. This dissertation thereby enables a deeper understanding of the complex conditions and constraints associated with visual information identification, the accurate capturing of user requirements, the appropriate specification and complexity of user queries, the execution of searches, and the reliability of performance indicators.

Declaration

"I, Michael Grubinger, declare that the PhD thesis entitled *Analysis and Evaluation of Visual Information Systems Performance* is no more than 100,000 words in length, exclusive of tables, figures, appendices, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work".

Signature Date

List of External Publications

Publications in journals and proceedings of peer reviewed conferences and workshops:

- Michael Grubinger, Clement H. C. Leung. A Benchmark for Performance Calibration in Visual Information Search. In *Proceedings of The 2003 International Conference on Visual Information Systems (VIS'2003)*, pages 414–419, Miami, FL, USA, September 2003. Knowledge Systems Institute.

- Paul Over, Clement H. C. Leung, Horace Ip, Michael Grubinger. Multimedia Retrieval Benchmarks. *Digital Multimedia on Demand, IEEE Multimedia April-June 2004*, pages 80–84, 2004.

- Michael Grubinger, Clement H. C. Leung. Incremental Benchmark Development and Administration. In *Proceedings of The Seventh International Conference of Visual Information Systems (VIS'2004)*, pages 328–333, San Francisco, CA, USA, September 2004. Knowledge Systems Institute.

- Michael Grubinger, Clement H. C. Leung, Paul D. Clough. The IAPR Benchmark for Assessing Retrieval Performance in Cross Language Evaluation Tasks. In *Proceedings of the MUSCLE ImageCLEF Workshop on Image and Video Retrieval Evaluation*, pages 33–50, Vienna, Austria, September 2005.

- Michael Grubinger, Paul D. Clough, Henning Müller, Thomas Deselaers. The IAPR TC-12 Benchmark - A New Evaluation Resource for Visual Information Systems. In *The Proceedings of the International Workshop OntoImage'2006*

Language Resources for Content-Based Image Retrieval, held in conjunction with LREC'06, pages 13–23, Genoa, Italy, May 2006.

- Michael Grubinger, Paul D. Clough, Clement H. C. Leung. The IAPR TC-12 Benchmark for Visual Information Search. *IAPR Newsletter April 2006*, Volume 28, Number 2, pages 10–12, 2006.

- Michael Grubinger, Clement H. C. Leung, Paul D. Clough. Linguistic Estimation of Topic Difficulty in Cross-Language Image Retrieval. In *Accessing Multilingual Information Repositories*, volume 4022 of *Lecture Notes in Computer Science (LNCS)*, pages 558–566, Vienna, Austria, September 2006. Springer.

- Paul D. Clough, Henning Müller, Thomas Deselaers, Michael Grubinger, Thomas Lehmann, Jeffery Jensen, William Hersh. The CLEF 2005 Cross-Language Image Retrieval Track. In *Accessing Multilingual Information Repositories*, volume 4022 of *Lecture Notes in Computer Science (LNCS)*, pages 535–557, Vienna, Austria, September 2006. Springer.

- Paul D. Clough, Michael Grubinger, Thomas Deselaers, Allan Hanbury, Henning Müller: Overview of the ImageCLEF 2006 photographic retrieval and object annotation tasks. *Evaluation of Multilingual and Multi-modal Information Retrieval*, *Lecture Notes in Computer Science (LNCS)*, Alicante, Spain, 2007. Springer - in press.

Publications in working papers and reports:

- Michael Grubinger. Benchmarking for Content Based Visual Information Search. *SCM6102 Research Project Report*, School of Computer Science and Mathematics, Victoria University of Technology, Melbourne, Australia, November 2002.

- Paul D. Clough, Henning Müller, Thomas Deselaers, Michael Grubinger, Thomas Lehmann, Jeffrey Jensen, William Hersh. The CLEF 2005 Cross-

Language Image Retrieval Track. In *CLEF Working Notes*, Vienna, Austria, September 2005.

- Michael Grubinger, Clement H. C. Leung, Paul D. Clough. Towards a Topic Complexity Measure for Cross-Language Image Retrieval. In *CLEF Working Notes*, Vienna, Austria, September 2005.

- Paul D. Clough, Michael Grubinger, Thomas Deselaers, Allan Hanbury, Henning Müller. Overview of the ImageCLEF 2006 photographic retrieval and object annotation tasks. In *CLEF Working Notes*, Alicante, Spain, September 2006.

Acknowledgements

Many wonderful people have both assisted and supported me during this dissertation, and I offer my thanks to all of them.

First and foremost, I am deeply indebted to my principal supervisor Clement H. C. Leung for his guidance, direction and the countless hours of support he provided during my candidature. I want to thank him for introducing me to the exciting domain of visual information retrieval, showing me the art of writing conference and journal papers, for his advice and feedback on my many proposals, and the regular discussions about my ideas as well as the issues and aspects surrounding my research. His deep knowledge and understanding as well as his contacts within the field of information retrieval have been invaluable for this research. I have benefited immeasurably from his tutelage and expertise.

This dissertation would have not been written without the help of Paul Clough from Sheffield University. Even though he has been extremely busy with his own duties and responsibilities, Paul has given up many hours of his valuable time to help me understand the aspects of text retrieval and the organisation of large-scale evaluation events. I want to thank him for giving me the chance to run my evaluation task at ImageCLEF, the endless Skype conversations, the fruitful discussions and his continuing help and valuable feedback with both publications as well as this dissertation.

I would also like to thank my other ImageCLEF colleagues: Henning Müller for his constructive and detailed feedback on my papers and publications, for establishing the contact with ImageCLEF and also for getting me started with LaTeX; Thomas Deselaers, Allan Hanbury and Mark Sanderson for their fruitful comments

on my work; and Carol Peters from CLEF for her support and providing the platform to facilitate the practical application of my research.

My thanks also go to Victoria University for funding this research with an International Postgraduate Research Scholarship, and to Lesley Birch for guiding me during the scholarship application process and her help with all scholarship related issues during the candidature. Further, to the School of Computer Science and Mathematics for providing me with the necessary resources to carry out my research. In particular, I would like to thank the Head of School, Pietro Cerone, and Janet Grady for their immense support and great cooperation; Cameron Giles, Mark Mojic and Danh Ho for their help and technical assistance; and Bai-Ling Zhang, Alasdair McAndrews and Ian Gomm for their valuable feedback, comments and input.

Special thanks to Angela Rojter for correcting my English, improving my academic writing skills and for those long and interesting discussions about grammar in general and the special nuances of Australian English in particular. To my dear friend Petra Siwek for having an independent and critical look at my introduction, and to Eder Kikianty for double-checking and fine-tuning the mathematical elaborations. To Gabriele Sorrentino, Jakub Szajman and Dennis Hammer for helping me out whenever I got stuck with LaTeX. To André Kiwitz and Stefan Richter from *viventura* for supporting this research and providing their valuable images for evaluation purposes.

To my research colleagues Mark Aquilina, Gary Howells, Guandong Xu, Hao Lan Zhang and Murali Krishna Reddy Danda for creating a stimulating and motivating work environment in our student research office. Special thanks go to Klautsi, Rex and Turba for keeping me company during my long and late office hours and making these times a little bit less lonely. I also want to thank my flatmate Chegon Hashim for supporting and nursing an often tired, injured and hungry Abang throughout the entire candidature.

Final thanks to my wonderful friends world-wide for standing by me and con-

tinuing that special friendship although they might not have seen me a lot in recent years. I miss the time that I could have otherwise spent with them, and I deeply appreciate their loyalty.

Last but not least, to my beautiful family in Austria, especially my Mum, my Dad and my two gorgeous sisters Andrea and Ingrid for their emotional support, continuous encouragement and everlasting love. Thank you so much for believing in me and always being there for me.

Contents

List of Figures

List of Tables