

**INTELLIGENT CONTENT-BASED IMAGE
RETRIEVAL FRAMEWORK BASED ON
SEMI-AUTOMATED LEARNING AND
HISTORIC PROFILES**

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I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary education institution.

A handwritten signature in blue ink, consisting of three Chinese characters: 鍾建平 (Chung Jianping).

.....
(KIEN-PING CHUNG)

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ABSTRACT

Over the last decade, storage of non text-based data in databases has become an increasingly important trend in information management. Image in particular, has been gaining popularity as an alternative, and sometimes more viable, option for information storage. While this presents a wealth of information, it also creates a great problem in retrieving appropriate and relevant information during searching. This has resulted in an enormous growth of interest, and much active research, into the extraction of relevant information from non text-based databases. In particular, content-based image retrieval (CBIR) systems have been one of the most active areas of research.

The retrieval principle of CBIR systems is based on visual features such as colour, texture, and shape or the semantic meaning of the images. To enhance the retrieval speed, most CBIR systems pre-process the images stored in the database. This is because feature extraction algorithms are often computationally expensive. If images are to be retrieved from the World-Wide-Web (WWW), the raw images have to be downloaded and processed in real time. In this case, the feature extraction speed becomes crucial. Ideally, systems should only use those feature extraction algorithms that are most suited for analysing the visual features that capture the common relationship between the images in hand. In this thesis, a statistical discriminant analysis based feature selection framework is proposed. Such a framework is able to select the most appropriate visual feature extraction algorithms by using *relevance feedback* only on the user labelled samples. The idea is that a smaller image sample group is used to analyse the appropriateness of each visual feature, and only the selected features will be used for image comparison and ranking. As the number of features is less, an improvement in the speed of retrieval is achieved. From

experimental results, it is found that the retrieval accuracy for small sample data has also improved. Intelligent E-Business has been used as a case study in this thesis to demonstrate the potential of the framework in the application of image retrieval system.

In addition, an inter-query framework has been proposed in this thesis. This framework is also based on the statistical discriminant analysis technique. A common approach in inter-query for a CBIR system is to apply the term-document approach. This is done by treating each image's name or address as a term, and the query session as a document. However, scalability becomes an issue with this technique as the number of stored queries increases. Moreover, this approach is not appropriate for a dynamic image database environment. In this thesis, the proposed inter-query framework uses a cluster approach to capture the visual properties common to the previously stored queries. Thus, it is not necessary to "memorise" the name or address of the images. In order to manage the size of the user's profile, the proposed framework also introduces a merging approach to combine clusters that are close-by and similar in their characteristics. Experiments have shown that the proposed framework has outperformed the short term learning approach. It also has the advantage that it eliminates the burden of the complex database maintenance strategies required in the term-document approach commonly needed by the inter-query learning framework. Lastly, the proposed inter-query learning framework has been further extended by the incorporation of a new semantic structure. The semantic structure is used to connect the previous queries both visually and semantically. This structure provides the system with the ability to retrieve images that are semantically similar and yet visually different. To do this, an active learning strategy has been incorporated for exploring the structure. Experiments have again shown that the proposed new framework has outperformed the previous framework.

LIST OF PUBLICATIONS

The following papers have reported the progress and results of work related to this thesis. Most of the earlier work was focused on relevance feedback for CBIR systems. Subsequently, the focus of the work was shifted to inter-query learning. Three papers have been published in refereed international journals and eleven papers have either been published, or will be published, in proceedings of international conferences.

Journal Papers

1. Chung, K., Fung, C. C., *Relevance Feedback and Intelligent Technologies in Content-Based Image Retrieval System for Medical Applications*, Australian Journal of Intelligent Information Processing Systems, (AJIIPS), vol. 8, pp. 113 – 122, 2004.
2. Chung, K., Fung, C. C., *A Hierarchical Nonparametric Discriminant Analysis Approach for WWW Content-Based Image Retrieval System*, International Journal of Electronic Business (IJEB), vol. 4, pp. 208 – 200, 2006.
3. Chung, K., Fung, C. C., *A Feature Vector Approach for Inter-Query Learning for Content-Based Image Retrieval System*, Journal of Advanced Computational Intelligence and Intelligent Informatics (JACIII), Vol.11 No.3, 2007.

Conference Papers

1. Chung, K., Fung, C. C., Hong, X., *A Study on the Content-Based Image Retrieval System for Medical Applications*, Proceedings of the 8th Australian and New Zealand Conference on Intelligence Information Systems, (ANZIIS '03), Sydney, Australia, 10th – 12th December 2003, pp. 451-456.
2. Chung, K., Fung, C. C., *Applications of Relevance Feedback and Intelligent Technologies in Content-Based Image Retrieval System in Medical Field*, Proceedings of the 4th International Conference on Intelligent Technology, (InTech '03), Chiang Mai, Thailand, December 17-19, 2003, pp. 679-686.
3. Chung K.P., Li J.B., Fung C.C. and Wong K.W., “A Parallel Architecture for Feature Extraction in Content-Based Image Retrieval System”, Proceedings of the IEEE Conference on Cybernetics and Intelligent Systems (CIS 2004) 1st – 3rd December 2004, Singapore, pp. 468-473.
4. Chung, K. and Fung, C. C., *A Hierarchical Discriminant Analysis Framework for Content-Based Image Retrieval System for Industrial Applications*, Proceedings of the 3rd International IEEE Conference on Industrial Informatics, (INDIN '05), Perth, Australia, 10th – 12th August 2005.
5. Chung, K. and Fung, C. C., *Multiple Layer Kernel-Based Approach in Relevance Feedback Content-based Image Retrieval System*, Proceedings of the 4th International Conference on Machine Learning Cybernetics, (ICMLC '05), Guangzhou, China, 18th – 21st August 2005, page 405 - 409.

6. Chung, K. and Fung, C. C., *A Hierarchical Nonparametric Discriminant Analysis Approach for a Content-Based Image Retrieval System*, Proceedings of the 2005 IEEE Conference on e-Business Engineering, (ICEBE '05), Beijing, China, 18th – 20th October 2005, page 346 - 351.
7. Chung, K. and Fung, C. C., *A Nonparametric Discriminant Approach in Resolving Complex Multi-class Query for Content-based Image Retrieval*, Proceedings of the 2005 IEEE Region 10 Conference, (TenCon '05), Melbourne, Australia, 21st – 24th November 2005.
8. Chung, K., Fung, C. C. and Wong, K. W., *A Feature Selection Framework for Small Sampling Data in Content-based Image Retrieval System*, Proceedings of the 5th International Conference on Information, Communications and Signal Processing, (ICICS '05), Bangkok, Thailand, 6th – 9th December 2005, pp. 310-314.
9. Chung, K., Fung, C. C., *Reducing User Log Size in an Inter-Query Learning Content-Based Image Retrieval (CBIR) System with a Cluster Merging Approach*, Proceedings of the 2006 International Joint Conference on Neural Networks, (IJCNN 2006), Vancouver, Canada, 16th – 21st July 2006, pp 2163-2170.
10. Chung, K., Chong, S., Fung, C. C., and Li, J. L., *The Application of User Log for Online Business Environment using Content-Based Image Retrieval System*, Proceedings of the IEEE International Conference on e-Business Engineering, (ICEBE 2006), Shanghai, China, 24th – 26th October 2006, page 2163 - 2167.

11. Fung, C. C. and Chung, K., *Establishing Semantic Relationship in Inter-Query Learning for Content-Based Image Retrieval System*, Proceedings of the 11th Pacific-Asia Conference on Knowledge Discovery and Data Mining, (PAKDD 2007), Nanjing, China, 22nd – 25th May 2007. Springer LNCS Vol. 4426, pp. 498-506.

CONTRIBUTIONS OF THE THESIS

The main contributions of this thesis are:

- A survey of various techniques developed and used in relevance feedback CBIR systems. In this study, it is realised that majority of reported literatures have made an important assumption that the image databases are mostly static. Such assumption is not applicable in a more dynamic environment such as the World-Wide-Web (WWW). Thus, it is the focus of this thesis in developing frameworks which are more suitable for a dynamic environment. This study has been published in conference papers 1 and 2. Conference paper 1 was later extended into journal paper 1. This study has been included in Chapter 3 of this thesis.
- A relevance feedback framework has been developed to improve the retrieval accuracy for small amounts of sample data, and to allow the system to select the most appropriate visual features for image retrieval. E-Business has been used as a case study to demonstrate the application of such framework in a dynamic environment. The study has shown the potential of such framework in WWW. In addition, this technique has been extended and implemented in a parallel computing architecture. The various techniques applied in this study have been published in conference papers 3 to 8. The practical aspect for commercial applications of this proposal has also been discussed and published in journal paper 2. The development of the new relevance feedback framework forms a part of Chapter 3.

- A survey of various approaches and techniques developed for inter-query learning in a CBIR system. Again, the study has identified that most of the reported literatures have based their study on a static environment. These reported findings are not suitable for a more dynamic environment. This study has been presented as part of conference paper 9 and is included in Chapter 4 of this thesis.
- An inter-query query framework has been proposed for a CBIR system to further improve the retrieval accuracy, based on previous query retrieval results. Test results have shown such framework outperformed the short term learning framework as proposed in Chapter 3 of this thesis. The findings have been presented in conference paper 9, and the practical aspect of the proposal has been presented in conference paper 10. Paper 11 is an extension of the proposal presented in paper 10. The proposal and the findings are also documented in Chapter 5 of this thesis.

ACRONYMS

BDA	Bias Discriminant Analysis
BFGS	Broyden-Fletcher-Goldfarb-Shanno Quasi-Newton method
BSVM	Bias Support Vector Machine
CBIR	Content-Based Image Retrieval
CBMIR	Content-Based Medical Image Retrieval
CCV	Colour Coherence Vector
CMY	Cyan Magnetic Yellow
CSS	Cascading Style Sheet
CT	Computed Tomography
EM	Expectation Maximisation
EMD	Earth Mover's Distance
GMM	Gaussian Mixture Model
GUI	Graphical User Interface
HSV	Hue Saturation Value
HTML	Hyper Text Markup Language
IRM	Integrated Region of Interest
KBDA	Kernel Bias Discriminant Analysis
KLT	Karhunen-Loeve Transform
LDA	Linear Discriminant Analysis
LSA	Latent Semantic Analysis
LSI	Latent Semantic Index
MDA	Multiple Discriminant Analysis
MRI	Magnetic Resonance Imaging
NDA	Nonparametric Discriminant Analysis
PACS	Picture Archiving and Communication Systems
QBC	Query By Committee
RBF	Radial Basis Function
RF	Relevance Feedback
RGB	Red Green Blue
ROI	Region of Interest
SOM	Self-Organization Map
SVD	Singular Value Decomposition
SVM	Support Vector Machine
TS-SOM	Tree-Structured Self-Organization Map
UFM	Unified Feature Matching
VF	Virtual Feature
WWW	World-Wide-Web
WWW-CBIR	World-Wide-Web-Content-Based Image Analysis
XML	Extensible Markup Language

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