COLOUR-BASED IMAGE RETRIEVAL ALGORITHMS BASED ON COMPACT COLOUR DESCRIPTORS AND DOMINANT COLOUR-BASED INDEXING METHODS

AHMED TALIB ABDULAMEER

DOCTOR OF PHILOSOPHY
UNIVERSITI UTARA MALAYSIA
2014

Permission to Use

In presenting this thesis in fulfilment of the requirements for a postgraduate degree from Universiti Utara Malaysia, I agree that the Universiti Library may make it freely available for inspection. I further agree that permission for the copying of this thesis in any manner, in whole or in part, for scholarly purpose may be granted by my supervisor(s) or, in their absence, by the Dean of Awang Had Salleh Graduate School of Arts and Sciences. It is understood that any copying or publication or use of this thesis or parts thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to Universiti Utara Malaysia for any scholarly use which may be made of any material from my thesis.

Requests for permission to copy or to make other use of materials in this thesis, in whole or in part, should be addressed to:

Dean of Awang Had Salleh Graduate School of Arts and Sciences
UUM College of Arts and Sciences
Universiti Utara Malaysia
06010 UUM Sintok

Abstrak

Capaian imej berasaskan kandungan (CBIR) dilaporkan sebagai salah satu bidang penyelidikan yang paling aktif dalam dua dekad lalu. Tiga masalah prestasi CBIR ialah ketidaktepatan dapatan semula imej, kerumitan yang tinggi ciri pengekstrakan, dan penurunan semula imej selepas pengindeksan pangkalan data, menyebabkan CBIR tidak sesuai digunakan pada peranti mudah alih. Objektif utama tesis ini adalah untuk meningkatkan prestasi CBIR. Untuk mencapai objektif ini, tiga kaedah telah digunakan. Kaedah pertama menggunakan imej warna dominan (DC) dipilih sebagai penyumbang utama untuk tujuan ini kerana ciri yang kompak dan keserasian dengan sistem visual manusia. Capaian semula imej berasaskan semantik adalah dicadangkan untuk menyelesaikan masalah capaian yang tidak tepat dengan menumpukan pada objek imej. Kesan latar belakang imej dikurangkan untuk memberi tumpuan lebih kepada objek dengan memberikan pemberat untuk objek dan latar belakang DC. Nisbah peningkatan ketepatan ditingkatkan berbanding kaedah yang dibandingkan. Rangka kerja DC pemberat adalah dicadangkan untuk mengitlak teknik ini di mana ianya ditunjukkan dengan menggunakannya pada perihalan warna. Manakala untuk mengurangkan kerumitan yang tinggi pada warna Correlogram daripada segi pengiraan dan ruang memori, kaedah kedua perwakilan padat Correlogram dicadangkan. Langkah persamaan yang sedia ada berasaskan DC Correlogram disesuaikan untuk meningkatkan ketepatannya. Kedua-dua kaedah digabungkan untuk menghasilkan pemerihal warna yang baik dari segi masa dan memori kerumitan ruang. Hasilnya, ketepatan telah ditingkatkan berbanding kaedah yang sedia ada dan ruang memori dikurangkan 10% kurang daripada ruang asalnya. Peralihan warna ke dalam beberapa rangka kerja DC dicadangkan untuk mengitlak konsep DC. Selain itu, kedua teknik pengindeksan berasaskan DC dicadangkan untuk mengatasi masalah pengindeksan dengan menggunakan RGB dan ruang warna persepsi LUV. Kajian ini menyumbang kepada pengurangan ruang carian pangkalan data serta pada masa yang sama memelihara ketepatan yang sama capaian imej berasakan kandungan.

Kata kunci: Capaian imej berasaskan kandungan, Correlogram warna dominan, Pengindeksan berasaskan warna, Perihalan warna padat.

Abstract

Content based image retrieval (CBIR) is reported as one of the most active research areas in the last two decades, but it is still young. Three CBIR's performance problem in this study is inaccuracy of image retrieval, high complexity of feature extraction, and degradation of image retrieval after database indexing. This situation led to discrepancies to be applied on limited-resources devices (such as mobile devices). Therefore, the main objective of this thesis is to improve performance of CBIR. Images' Dominant Colours (DCs) is selected as the key contributor for this purpose due to its compact property and its compatibility with the human visual system. Semantic image retrieval is proposed to solve retrieval inaccuracy problem by concentrating on the images' objects. The effect of image background is reduced to provide more focus on the object by setting weights to the object and the background DCs. The accuracy improvement ratio is raised up to 50% over the compared methods. Weighting DCs framework is proposed to generalize this technique where it is demonstrated by applying it on many colour descriptors. For reducing high complexity of colour Correlogram in terms of computations and memory space, compact representation of Correlogram is proposed. Additionally, similarity measure of an existing DC-based Correlogram is adapted to improve its accuracy. Both methods are incorporated to produce promising colour descriptor in terms of time and memory space complexity. As a result, the accuracy is increased up to 30% over the existing methods and the memory space is decreased to less than 10% of its original space. Converting the abundance of colours into a few DCs framework is proposed to generalize DCs concept. In addition, two DC-based indexing techniques are proposed to overcome time problem, by using RGB and perceptual LUV colour spaces. Both methods reduce the search space to less than 25% of the database size with preserving the same accuracy.

Keywords: Content-based image retrieval, Dominant colour correlogram, Colour-based indexing, Compact colour descriptors.

Acknowledgement

To begin, the praise be to Allah (S.W.T). It is impossible for me to accomplish this work without the blessing of Allah and contribution from so many gracious people who have given me all sorts of assistance. To these people, I am indeed grateful.

First of all, I would like to express my deepest gratitude to my supervisors, Dr. Massudi Mahmuddin, Dr. Husniza Husni and Associate Professor Dr. Loay E. George for their guidance and support throughout my study. I cannot fully express my appreciation to their exceptional efforts every time I need them. So, thank you very much and I really appreciate your help.

I believe that words are not enough to express my appreciation to my parents, brothers, sisters and relatives for their love and continuous pray. What I know is that I am indebted to them for being patient, inspiring and supportive of all time.

Grateful appreciation is also offered to all friends who have given valuable advice and support to me for completing this research, my wife Mrs. Dalia Abdulhadi, Dr. Naseer Ali, Ghassan Nashat, Ayad Hameed, Rafid Sagban and Mohammed Fadhil. Special thanks are also extended to Mr. Abdulhadi Abdulameer, Mr. Mohammed Sahib, Dr. Nashat Jassim and all other individual friends who have kept my cheerful along this journey. To those who I couldn't name them specifically here because there are simply so many of them, I offer my apology. But I am deeply indebted to them for their kindness and generosity.

Last but not least, heartiest thank you to my wife Dalia for her love, patience, everlasting support and constant motivation. Without her nothing would be possible. My deepest gratitude goes to my beloved son Yousif, for his love, patience and for being so wonderful. Although she knew nothing about it, my youngest daughter Tara has been the cutest piece in my life.

Table of Contents

Permission to Use i
Abstrak ii
Abstract iii
Acknowledgement iv
Table of Contents v
List of Tables ix
List of Figures xii
List of Abbreviations xvi

CHAPTER ONE INTRODUCTION 1
1.1 Introduction 1
1.2 Motivations 4
1.3 Problem Statement 6
1.4 Research Objectives 8
1.5 Significance of Research 10
1.6 Scope and Limitations 11
1.7 Research Summary 12
1.8 Thesis Organization 15

CHAPTER TWO LITERATURE REVIEW 17
2.1 Content-Based Image Retrieval 17
2.1.1 Query Formulation 19
2.1.2 Visual Feature Extraction 21
2.1.3 Indexing Methods 23
2.1.4 Similarity Measure 25
2.1.5 Image Databases for CBIR 29
2.1.6 Performance Evaluation 30
2.1.7 CBIR Applications and Systems 35
2.2 Dominance of Large Background in Colour Descriptors 37
2.2.1 Global Colour Descriptors 39
2.2.2 Local Invariant Descriptors 43

2.2.3 Similarity Measure of Colour Descriptors 45
2.3 Applicability of Colour Descriptors in Large Databases 48
2.3.1 Global Colour Descriptors 50
2.3.2 Spatial Colour Descriptors 51
2.3.3 Dominant Colour-based Methods 55
2.4 Reduction of Search Space in Large Databases 58
2.4.1 Feature Extraction Methods for CBIR 59
2.4.2 Indexing methods for CBIR 61
2.4.3 Colour-based Indexing Methods for CBIR 65
2.5 Chapter Summary 71
CHAPTER THREE RESEARCH METHODOLOGY 74
3.1 Design Research Methodology 74
3.2 CBIR Settings for this Research 77
3.2.1 Query Formulations 78
3.2.2 Visual Feature Extraction 78
3.2.3 Indexing Methods 79
3.2.4 Similarity Measure 80
3.2.5 Image Datasets 80
3.2.6 Performance Evaluation 84
3.2.7 CBIR Applications 88
3.3 Summary 89
CHAPTER FOUR A WEIGHTED DOMINANT COLOUR DESCRIPTOR ... 90
4.1 Current Problem of DC-based CBIR Methods 90
4.2 Weighted Dominant Colour Descriptor 92
4.2.1 Border Weight of Dominant Colours 93
4.2.2 Salient Object Detection 97
4.2.3 Extracting Final Weight of Dominant Colours 100
4.2.4 Similarity Measure of the Proposed WDCD 103
4.3 Similarity Measure Level-based Solution 109
4.4 Experimental Evaluation 111
4.4.1 Experimental Setup 111

4.4.2 Retrieval Performance 114
4.5 Summary 124

CHAPTER FIVE A COMPACT-GENERALIZED DOMINANT-COLOUR CORRELOGRAM DESCRIPTORS 126

5.1 The Problem of Colour Correlogram 127
5.2 Compact-Generalized Correlogram Descriptor 129
5.2.1 Colour Reduction 130
5.2.2 Distance Reduction 134
5.3 The Adapted DC-based Correlogram Descriptor 138
5.3.1 A Proposed Duo-Model for DC-based *ColGrm* Dissimilarity Measure 143
5.3.2 A Weighted DC-based Correlogram 148
5.4 Experimental Evaluation of Correlogram 154
5.4.1 Experimental Setup 154
5.4.2 Retrieval Performance 156
5.5 Generalizing both of Large Quantized Colours into Few Dominant Colours Conversion and Weighting of Dominant Colours Methods 171
5.5.1 Border-Interior pixel Classification method Overview 172
5.5.2 Dominant Colours-based BIC Approach 174
5.5.3 Weighted DC-based BIC 179
5.5.4 Experimental Evaluation of BIC 180
5.5.5 Generic Frameworks for Converting Large number of Colours into Few DCs and Weighting DCs 183
5.6 Summary 187

CHAPTER SIX DOMINANT COLOUR-BASED INDEXING METHODS 189

6.1 Problem of Colour-based Indexing Methods 189
6.2 RGB Indexing Method 190
6.2.1 Maximum Distance between Similar Colours 191
6.2.2 Indexing Structure 193
6.2.3 Searching Process 203
6.2.4 Experimental Evaluation 210
6.3 LUV Indexing Method 244

6.3.1 Indexing Structure....246
6.3.2 Searching Process....251
6.3.3 Experimental Evaluation....254
6.4 Summary....290
CHAPTER SEVEN CONCLUSION AND FUTURE WORK....291
7.1 Contributions....291
7.1.1 Weighted dominant colour descriptor....292
7.1.2 A compact representation of colour correlogram....293
7.1.3 An enhanced colour indexing methods....294
7.2 Future Work....295
REFERENCES....299

List of Tables

Table 1.1: Research Questions, Objectives, Methods and Outcomes Table.....13
Table 2.1: Comparison of different Indexing methods 65
Table 3.1: Summary of the datasets that are used in the research.....83
Table 4.1: Final DC's Weights extraction from original image using three inputs – SOW, BW and DCW. 101
Table 4.2: Values of SOW, BW, DCW and Final Weights of DCs in the three cartoon images presented in Figure 4.5.....107
Table 4.3: SIM^{yang} (Eq. 4.8) and SIM^{W} (Eq. 4.11) similarity measure for Figure 4.5 108
Table 4.4: Evaluation Metrics for Corel-1K dataset. 114
Table 4.5: Improvement Percentages of the proposed descriptor WDCD over original LBA and MPEG-7 descriptors in Corel-1K database. 116
Table 4.6: Evaluation metrics for competing descriptors on Caltech-26 dataset.....117
Table 4.7: Improvement Percentages of the proposed descriptor WDCD over existing descriptors on Caltech-26 database. 118
Table 4.8: Four evaluation metrics for competing descriptors applied on Cartoon-5K dataset.....119
Table 4.9: Improvement Ratio of the proposed descriptor WDCD over existing descriptors in Cartoon-5K database. 121
Table 4.10: Average Feature Extraction Time required for the proposed descriptor and the two compared descriptors.....124
Table 5.1: Comparison between Original and Perceptual ColGrm dissimilarity measures.....141
Table 5.2: Four Evaluation Metrics for all competing Correlogram descriptors on Corel-10K database.....158
Table 5.3: Improvement Percentages of Proposed CGC over AutoCorrelogram Adapted DCBC over Original Correlogram and Weighted DCBC over DCBC in setting 27 colours and distance=5. 158
Table 5.4: Memory Space for Features' Database of all competing descriptors for Corel-10K dataset and 27 Colours. 163

Table 5.5: Evaluation metrics for all Correlogram descriptors on Corel-10K database. 164
Table 5.6: Accuracy Improvement Percentages of Proposed CGC over AutoCorrelogram and Weighted DCBC in setting 64 colours and distance=5. 164
Table 5.7: Size of Features for all competing descriptors of 64 colours in Corel-10K Database. 165
Table 5.8: Evaluation metrics for all Correlogram descriptors on Cartoon-11K database with 27 colours. 169
Table 5.9: Improvement Percentages of Adapted DCBC over Correlogram and Weighted DCBC over DCBC in setting 27 colours and distance=5 in Cartoon-11K dataset. 169
Table 5.10: Evaluation metrics for all Correlogram descriptors on Cartoon-11K database with 64 colours. 170
Table 5.11: Accuracy Improvement Percentages of Proposed CGC over AutoCorrelogram and Weighted DCBC in setting 64 colours and distance=5 in Cartoon-11K dataset. 170
Table 5.12: ANMRR, ARR, P(10) and MAP values for all BIC versions on Cartoon-11K database with 158 queries. 181
Table 5.13: Storage Space, Time and No. of histogram bins performance metrics for all BIC versions on Cartoon-11K database with 158 queries. 181
Table 5.14: Accuracy Improvement Ratio of proposed BIC methods over original BIC method. 182
Table 6.1: An illustration of colour quantization method that applied in Figure 6.4. 194
Table 6.2: An Average of Overhead Ratio of the proposed indexing method in two different datasets. 213
Table 6.3: Accuracy and Efficiency metrics for Correlogram Descriptor using sequential search and all competing indexing methods applied on Cartoon-11K Dataset. 219
Table 6.4: Accuracy and Efficiency metrics for AutoCorrelogram Descriptor using sequential search and all competing indexing methods applied on Cartoon-11K Dataset. 224

Table 6.5: Accuracy and Efficiency metrics for MPEG-7 Dominant Colour Descriptor using sequential search and all competing indexing methods applied on Cartoon-11K Dataset. 226
Table 6.6: Accuracy and Efficiency metrics for DC based-Correlogram Descriptor using sequential search and all competing indexing methods applied on Cartoon-11K Dataset. 228
Table 6.7: Evaluation metrics for Weighted DC-based Correlogram using sequential search and all competing indexing methods applied on Cartoon-11K Dataset. 230
Table 6.8: R values of Different Colour Thresholds and the corresponding theoretical Percentage of the visited colours in RGB space 250
Table 6.9: Evaluation metrics for ColGrm descriptor using sequential search, competing indexing methods and LUV indexing method applied on Cartoon-11K Dataset. 256
Table 6.10: Evaluation metrics for Autocorrelogram descriptor using sequential search, competing indexing methods and LUV indexing applied on Cartoon-11K Dataset. 266
Table 6.11: Evaluation metrics for MPEG-7 DCD using sequential search and all competing indexing methods including LUV indexing applied on Cartoon-11K Dataset. 269
Table 6.12: Evaluation metrics for DCBC descriptor using sequential search, competing indexing methods and LUV indexing applied on Cartoon-11K Dataset. 274
Table 6.13: Evaluation metrics for Weighted DC-based ColGrm using sequential search, competing indexing methods and LUV indexing applied on Cartoon-11K Dataset. 279

List of Figures

Figure 1.1: CBIR performance influencing factors and their related issues 3
Figure 2.1: Components of CBIR System (adopted from Tran, 2003). 18
Figure 2.2: Types of query in CBIR (adopted from Siggelkow, 2002) 20
Figure 2.3: Relation of Database with other components of CBIR System.....30
Figure 2.4: Images of the same colour percentages with different colour distributions 51
Figure 2.5: Taxonomy of CBIR Indexing Methods 63
Figure 2.6: Illustration of locating the query image on border of SP, lattice structure and cluster. 67
Figure 2.7: Explanation of the new Threshold values of the method proposed by (Yildizer et al., 2012). 69
Figure 2.8: Key Factors and issues of the CBIR performance and related Solutions and Contributions in this Research 71
Figure 2.9: Diagram of research approach. 73
Figure 3.1: Proposed Design Research Methodology. 75
Figure 3.2: Accuracy metrics that are used in this research.....87
Figure 4.1: The way an image gives weight to each DC depending on whether it is an object or background. 94
Figure 4.2: Three images that explain the conflict cases with border weight method. 96
Figure 4.3: Two images examples on salient object extraction steps. 98
Figure 4.4: Examples to illustrate the inaccuracy of the SOD methods, (a) GC-SRD and (b) LoG. 100
Figure 4.5: Examples to show the effectiveness of the proposed WDCD in object-based image retrieval.....106
Figure 4.6: Samples from Cartoon-5K Dataset. 112
Figure 4.7: Visual Comparison of the proposed WDCD with MPEG-7 and LBA DCD in Corel-1K Dataset. 115
Figure 4.8: Visual Comparison of the proposed WDCD with MPEG-7 and LBA DCD in Caltech-26 Dataset. 117

Figure 4.9: Visual Comparison of the proposed WDCD with MPEG-7 and LBA DCD in Cartoon-5K Dataset. 120
Figure 4.10: An example to show outperformance of MPEG-7 and LBA DCDs over the proposed WDCD in some queries. 123
Figure 5.1: Original colour Correlogram feature vector representation, of complexity $O(m^2d)$. 130
Figure 5.2: An example of computing ColGrm Table to Image's Window. 131
Figure 5.3: New ColGrm matrix representations. 133
Figure 5.4: Complexity of the proposed Compact ColGrm descriptor (shaded cells only) compared with the Original One. 137
Figure 5.5: Complexity of the proposed Compact-Generalized Correlogram in all stages of CBIR System. 138
Figure 5.6: An overview of Perceptual Correlogram (source: Kiranyaz et al., 2012). 139
Figure 5.7: The drawback of ColGrm dissimilarity measure (P_{Corr}) of Perceptual ColGrm compared with that of Original ColGrm. 143
Figure 5.8: An example of original ColGrm matrix of two images with not matched colours. 144
Figure 5.9: An example of colours percentages match with main diagonal of ColGrm. 147
Figure 5.10: Visual Results of eight competing descriptors on Corel-10K database 159
Figure 5.11: Visual Results of Seven Competing Descriptors on Cartoon-11K database. 167
Figure 5.12: Results of BIC to show Border and Interior Pixels classification. 174
Figure 5.13: Similarity Measure for two images in original BIC method. 176
Figure 5.14: Similarity Measure for two images in the proposed DC-based BIC. 176
Figure 5.15: Large Number of Colours into Few DCs Conversion Generic Framework. 184
Figure 5.16: Weighting DC-based Descriptors Generic Framework. 184
Figure 6.1: An example of colour quantization of DCD. 194

Figure 6.2: Weights and values of bits for three colour channels (R, G, B) after quantization. 195
Figure 6.3: Building index structure from colour channels. 196
Figure 6.4: Obtaining indexing values from colour channels values. 196
Figure 6.5: Structure of proposed RGB Indexing Method 197
Figure 6.6: Single Level B+-Tree for representing Colour Percentages 202
Figure 6.7: Indexing Structure with B+-Tree to represent Colour Percentages 203
Figure 6.8: Image retrieval process when colour tolerance value = 0. 205
Figure 6.9: Image retrieval process when colour tolerance value = 8. 208
Figure 6.10: Image retrieval process when colour tolerance value = 24. 209
Figure 6.11: An example of instability of MAP Accuracy Metric in Indexing Method because its dependence on all relevant images instead of relevant retrieved images. 215
Figure 6.12: Comparison the accuracy of indexing methods on ColGrm Descriptor using (a) P(10) and (b) ANMRR. 234
Figure 6.13: Comparison the accuracy of indexing methods on MPEG-7 DCD using (a) P(10) and (b) ANMRR. 236
Figure 6.14: Comparison the accuracy of indexing methods on DC-based ColGrm using (a) P(10) and (b) ANMRR. 237
Figure 6.15: Comparison the Search Space Ratio (SSR) for Cartoon-11K dataset on (a) different settings using Octree and (b) Octree vs. Octree+CPF. 238
Figure 6.16: Comparison the accuracy of indexing methods on MP7DCD in Corel-10K database using (a) P(10) and (b) ANMRR. 240
Figure 6.17: Comparison the accuracy of indexing methods on ColGrm in Corel-10K database using (a) P(10) and (b) ANMRR. 241
Figure 6.18: Comparison the accuracy of indexing methods on DCBC in Corel-10K database using (a) P(10) and (b) ANMRR. 242
Figure 6.19: Comparison the Search Space Ratio of indexing methods in Corel-10K dataset using (a) different settings of Octree and (b) Octree vs.Octree+CPF. 243
Figure 6.20: A Second Proposed Indexing Method for perceptual colour spaces. 247
Figure 6.21: Illustration of Search Range when different LUV Colour Distances are applied. 250

Figure 6.22: Image Retrieval Process using second proposed LUV indexing.....253
Figure 6.23: Accuracy metrics of the proposed LUV indexing compared with other indexing methods in Correlogram using (a) P(10) and (b) ANMRR. 260
Figure 6.24: An example of Colour Percentage- and Colour Weight-based Sorting in the proposed LUV Indexing.....262
Figure 6.25: Comparison between colour percentage-based indexing method and Colour weight-based indexing method (WLuvCPF indexing). 264
Figure 6.26: SSR comparison for (a) LUV indexing in different settings and (b) CP- and CW-based sorting methods of LUV indexing.....265
Figure 6.27: Accuracy metrics of LUV indexing compared with other indexing methods in MPEG-7 DCD using (a) P(10) and (b) ANMRR.....272
Figure 6.28: Comparison between Colour Percentage- and Colour Weight-based indexing method in MPEG-7 DCD using (a) P(10) and (b) ANMRR.....273
Figure 6.29: Accuracy metrics of LUV indexing compared with other indexing methods in DC-based ColGrm using (a) P(10) and (b) ANMRR.....277
Figure 6.30: Comparison between Colour Percentage- and Colour Weight-based indexing method in DC-based ColGrm using (a) P(10) and (b) ANMRR. 278
Figure 6.31: Accuracy metrics of LUV indexing compared with other indexing methods in ColGrm in Corel-10K dataset using (a) P(10) and (b) ANMRR.....283
Figure 6.32: Comparison between Colour Percentage- and Colour Weight-based indexing methods in ColGrm descriptor using (a) P(10) and (b) ANMRR.....284
Figure 6.33: SSR comparison for (a) different settings in LUV indexing and (b) CP- and CW-based sorting methods in LUV indexing.....285
Figure 6.34: Accuracy metrics of LUV indexing compared with other indexing methods in MPEG-7 DCD using (a) P(10) and (b) ANMRR.....286
Figure 6.35: Comparison between Colour Percentage- and Colour Weight-based indexing methods in MPEG-7 DCD using (a) P(10) and (b) ANMRR. 287
Figure 6.36: Accuracy metrics of LUV indexing compared with other indexing methods in DCBC using (a) P(10) and (b) ANMRR. 288
Figure 6.37: Comparison between Colour Percentage- and Colour Weight-based indexing methods in DCBC using (a) P(10) and (b) ANMRR. 289

List of Abbreviations

ANMRR	Average Normalized Modified Retrieval Rank
AP	Average Precision
ARR	Average Retrieval Rate
BIC	Border/Interior Pixel Classification
BOVW	Bag of Visual Words
CBIR	Content-based Image Retrieval
CBIRS	Content-based Image Retrieval System
CCV	Colour Coherence Vectors
CLEF	Cross Language Evaluation Forum
ColGrm	Colour Correlogram
CSD	Colour Structure Descriptor
DC	Dominant Colour
DCBC	Dominant Colour-based Correlogram
DCD	Dominant Colour Descriptor
DQM	Dynamic Quantization Method
EMD	Earth Mover's Distance
FV	Feature Vector
GB	Giga bytes
GCD	Global Colour Descriptor
GLA	Generalized Lloyd Algorithm
HSV	Hue, Saturation, Value Colour Space
k-NN	k-Nearest Neighbours
LBA	Linear Block Algorithm
LUV	Adams Chromatic Valence Colour Space
MAP	Mean Average Precision
MB	Mega bytes
MP7DCD	MPEG-7 Dominant Colour Descriptor
MPHSM	merging palette histogram for similarity measure
NMRR	Normalized Modified Retrieval Rank

NN	Neural Networks
P	Precision
QBE	Query by Example
QBS	Query by Sketch
QSM	Quadratic Similarity Measure
R	Recall
RGB	Red, Green, Blue Colour Space
RF	Relevance Feedback
SCD	Spatial Colour Descriptor
SM	Similarity Measure
SOM	Self-Organization Map
SVM	Support Vector Machines
WDCD	Weighted Dominant Colour Descriptor

CHAPTER ONE
INTRODUCTION

1.1 Introduction

The widespread of digital images and availability of huge storage space led to emergence of massive image collections, which are called *digital image libraries* (Attig, Copeland & Pelikan, 2004). These digital libraries spread on the Internet through the progress of transmission techniques. The wealth of available digital data, especially images, has introduced a problem to those who are seeking information in the digital libraries. This problem lays in managing and organizing these digital image libraries (databases). Therefore, *Indexing and Retrieval* concepts were introduced; *Indexing* relates to "how to store images in database and to retrieve them later (through querying) efficiently", whereas *Retrieval* relates to "how to retrieve images that are relevant to the query from images' database". Both concepts relate with the question of "how to speed up retrieval of the relevant images from databases?"

There are two methods to retrieve images from digital library according to Torres and Falcao (2006). These methods are generally known as image retrieval methods. The first method is Annotation-Based Image Retrieval (ABIR) that depends on metadata associated with each image and use traditional query techniques to retrieve images from database by a keyword (Mehyar & Atoum, 2012; Torres & Falcão, 2006). There are two disadvantages in this method (Chang, Tsai & Chou, 2013; Eitz, Hildebrand, Boubekeur & Alexa, 2010; Poursistani, Nezamabadi-pour, Askari Moghadam & Saeed, 2013). Firstly, it requires annotation of all images in the

The contents of the thesis is for internal user only

REFERENCES

Aboulmagd, H., El-Gayar, N., & Onsi, H. (2009). A new approach in content-based image retrieval using fuzzy. *Telecommunication Systems, 40*(1-2), 55-66. doi: 10.1007/s11235-008-9142-9.

Achanta, R., Estrada, F., Wils, P., & Susstrunk, S. (2008). Salient region detection and segmentation. In *Computer Vision Systems* (pp. 66-75). Springer Berlin Heidelberg.

Achanta, R., Hemami, S., Estrada, F., & Susstrunk, S. (2009). Frequency-tuned salient region detection. *IEEE Conference on Computer Vision and Pattern Recognition*, 1597–1604.

Alaoui, R., Ouatik, S., Alaoui, E., & Meknassi, M. (2009). Spatial Color Indexing: An Efficient and Robust Technique for Content- Based Image Retrieval. *Journal of Computer Science, 5* (2), 109-114.

Alexandrov, A. D., Ma, W.Y., Abbadi, A. El, & Manjunath, B. S. (1995). Adaptive Filtering And Indexing For Image Databases. *Proceedings of International Society for Optical Engineering (SPIE)- Storage and Retrieval for Image and Video Databases*.

Arampatzis, A., Zagoris, K., & Chatzichristofis, S. A. (2013). Dynamic two-stage image retrieval from large multimedia databases. Information Processing & Management, 49(1), 274-285.

Arslan, S., Yazıcı, A., Saçan, A., Toroslu, I. H., & Acar, E. (2013). Comparison of feature-based and image registration-based retrieval of image data using multidimensional data access methods. Data & Knowledge Engineering, 86(0), 124-145. doi: http://dx.doi.org/10.1016/j.datak.2013.01.007.

Attig, J., Copeland, A., & Pelikan, M. (2004). Context and Meaning: The Challenges of Metadata for a Digital Image Library within the University. *College & Research Libraries, 65*(3) 251-261.

Aulia, E. (2005). *Hierarchical Indexing for Region Based Image Retrieval*. M.Sc thesis, Louisiana State University.

Babu, G. P., Mehtre, B. M., & Kankanhalli, M. S. (1995). Color indexing for efficient image retrieval. *Multimedia Tools and Applications, 1* (2), 327–348.

Beckmann, N., Kriegel, H., Schneider, R., & Seeger, B. (1990). The R* -tree, an efficient and robust access method for points and rectangles. *Proceedings ACM Special Interest Group on Management of Data, International Conference Management Data*, 322–331.

Bentley, J. L. (1979). Multidimensional Binary Search Trees in Database Applications. *IEEE Transactions on Software Engineering, SE-5*(4), 333-340. doi: 10.1109/tse.1979.234200

Bohm, C., Berchtold, S., & Keim, D. A. (2001). Searching in high-dimensional spaces: Index structures for improving the performance of multimedia databases. *ACM Computing Survey, 33*(3), 322-373. doi: 10.1145/502807.502809

Boykov, Y. Y., & Jolly, M. P. (2001). Interactive graph cuts for optimal boundary & region segmentation of objects in ND images. In *Proceedings of Eighth IEEE*

International Conference on Computer Vision ICCV 2001 (Vol. 1, pp. 105-112).

Broek, E. V. D., Kisters, P., & Vuurpijl, L. (2004). The utilization of human color categorization for content-based image retrieval. In *Proceedings of International Society for Optical Engineering (SPIE), 5292*, 351–362.

Buckley, C., & Voorhees, E. M. (2004). Retrieval evaluation with incomplete information. Paper presented at the *Proceedings of the 27th annual international ACM SIGIR conference on Research and development in information retrieval*.

Cai, W., Song, Y., & Feng, D. D. (2012). Regression and classification based distance metric learning for medical image retrieval. Paper presented at *the 9th IEEE International Symposium on Biomedical Imaging (ISBI)*, 2012.

Carneiro, G., & Vasconcelos, N. (2005). A database centric view of semantic image annotation and retrieval. Paper presented at *the Proceedings of the 28th annual international ACM SIGIR conference on Research and development in information retrieval.*

Carson, C., Belongie, S., Greenspan, H., & Malik, J. (2002). Blobworld: Image Segmentation Using Expectation-Maximization and Its Application to Image Querying. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 24* (8), 1026-1038.

Catalan, J. A., & Jin, J. S. (2000). Dimension reduction of texture features for image retrieval using hybrid associative neural networks. Paper presented at *IEEE International Conference on the Multimedia and Expo, ICME 2000.*

Celebi, E., & Alpkocak, A. (2000). Clustering of texture features for content-based image retrieval. In *Advances in Information Systems* (pp. 216-225). Springer Berlin Heidelberg.

Chang, S.-F., Sikora, T., & Purl, A. (2001). Overview of the MPEG-7 standard. *IEEE Transactions on Circuits and Systems for Video Technology, 11*(6), 688-695.

Chang, B.-M., Tsai, H.-H., & Chou, W.-L. (2013). Using visual features to design a content-based image retrieval method optimized by particle swarm optimization algorithm. *Engineering Applications of Artificial Intelligence, 26*(10), 2372-2382. doi: http://dx.doi.org/10.1016/j.engappai.2013.07.018.

Chen, T., Cheng, M.-M., Tan, P., Shamir, A., & Hu., S.-M. (2009). Sketch2photo: Internet image montage. *ACM Transaction Graphics*, *28*(5), 1–10.

Chen, Y., Wang, J. Z., & Krovetz, R. (2005). CLUE: Cluster-based Retrieval of Images by Unsupervised Learning. *IEEE Transactions on Image Processing, 14*, 1187-1201.

Chen, Y., Zhou, X. S., & Huang, T. S. (2001). One-class SVM for learning in image retrieval. Paper presented at *International Conference on the Image Processing, 2001*.

Cheng, M.-M., Zhang, G.-X., Mitra, N. J., Huang, X., & Hu, S.-M. (2011). Global Contrast based Salient Region Detection. *24th IEEE Conference on Computer Vision and Pattern Recognition*, 409-416.

Chinlek, S., & Premchaiswade, W. (2001). Image retrieval using AC/CDC. Paper presented at *the Proceedings of International Symposium on Communications and Information Technologies, 2001*.

Chun, Y., Kim, N., & Jang, I. (2008). Content-based image retrieval using multi-resolution color and texture features. *IEEE Transactions on Multimedia, 6*(10), 1073–1084.

Clough, P., Grubinger, M., Deselaers, T., Hanbury, A., & Muller, H. (2007). Overview of the ImageCLEF 2006 photographic retrieval and object annotation tasks. *In Evaluation of Multilingual and Multi-modal Information Retrieval* (pp. 579-594). Springer Berlin Heidelberg.

Cour, T., & Shi, J. (2007). Recognizing Objects by Piecing Together the Segmentation Puzzle. *IEEE Conference on Computer Vision and Pattern Recognition.*

Das, M., Riseman, E. M., & Draper, B. A. (1997). FOCUS: Searching for Multi-colored Objects in a Diverse Image Database. *Proceedings of Computer Vision and Pattern Recognition*, 756-761.

Datta, R., Joshi, D., Li, J., & Wang, J. Z. (2008). Image retrieval: Ideas, influences, and trends of the new age. *ACM Computing Surveys (CSUR), 40*(2), 5.

Datta, R., Li, J., & Wang, J. Z. (2005). Content-based image retrieval: approaches and trends of the new age. Paper presented at *the Proceedings of the 7th ACM SIGMM international workshop on Multimedia information retrieval*, Hilton, Singapore.

Deng, H., Zhang, W., Mortensen, E., Dietterich, T., & Shapiro, L. (2007). Principal curvature-based region detector for object recognition. Paper presented at *the IEEE Conference on Computer Vision and Pattern Recognition, 2007 (CVPR'07).*

Deng, Y., Kenney, C., Moore, M. S., & Manjunath, B. S. (1999). Peer group filtering and perceptual color quantization. *IEEE International Symposium of Circuits System VLSI (ISCAS'99), 4*, 21–24.

Deng, Y., Manjunath, B. S., Kenney, C., Moore, M. S., & Shin, H. (2001). An efficient color representation for image retrieval. *IEEE Transaction on Image Processing, 10 (1),* 140–147.

Deza, E., & Deza, M. M. (2009). Encyclopedia of Distances. Springer Book, page 94.

Do, M. N., & Vetterli, M. (2002). Wavelet-based texture retrieval using generalized Gaussian density and Kullback-Leibler distance. *IEEE Transactions on Image Processing, 11*(2), 146-158.

Dobrescu, M., Stoian, M., & Leoveanu, C. (2010). Multi-modal CBIR Algorithm Based on Latent Semantic Indexing. Paper presented at *the Fifth International Conference on Internet and Web Applications and Services*, Barcelona, Spain.

Duaimi, M. G. (2006). *Development of A Content-based Image Retrieval System.* PhD Thesis, Al-Nahrain University, Baghdad, Iraq.

Park, D.-S., Park, J.-S., Kim, T. Y., & Han, J. H. (1999). Image indexing using weighted color histogram. Paper presented at *the Proceedings International Conference on Image Analysis and Processing.*

Eakins, J. P., & Graham, M. E. (1999). *Content-Based Image Retrieval: A Report to the JISC Technology Applications Programme*. Institute for Image Data Research, University of Northumbria, Newcastle.

Eitz, M., Hildebrand, K., Boubekeur, T., & Alexa, M. (2010). An evaluation of descriptors for large-scale image retrieval from sketched feature lines. Computers & Graphics, 34(5), 482-498.

ElAlami, M. E. (2011). Unsupervised image retrieval framework based on rule base system. Expert Systems with Applications, 38(4), 3539-3549.

Everingham, M., Zisserman, A., Williams, C. K., Van Gool, L., Allan, M., Bishop, C. M., . . . Dorkó, G. (2006). The 2005 pascal visual object classes challenge Machine Learning Challenges. In *Evaluating Predictive Uncertainty, Visual Object Classification, and Recognising Tectual Entailment* (pp. 117-176): Springer.

Fagin, R., Kumar, R., & Sivakumar, D. (2003). Efficient similarity search and classification via rank aggregation. Paper presented at *the Proceedings of the 2003 ACM SIGMOD international conference on Management of data.*

Faloutsos, C., Barber, R., Flickner, M., Hafner, J., Niblack, W., Petkovic, D., & Equitz, W. (1994). Efficient and effective querying by image content. *Journal of intelligent information systems, 3*(3-4), 231-262.

Fang, Y., Geman, D., & Boujemaa, N. (2005). An interactive system for mental face retrieval. In *ACM Special Interest Group on Multimedia (SIGMM), International workshop on Multimedia information retrieval*, 193-200.

Fauqueur, J., & Boujemaa, N. (2002). Region-Based Image Retrieval: Fast Coarse Segmentation and Fine Color Description. In *Proceedings of IEEE International Conference on Image Processing (ICIP'2002)*, Rochester, USA.

Fei-Fei, L., Fergus, R., & Perona, P. (2004). Learning generative visual models from few training examples: an incremental bayesian approach tested on 101 object categories. Paper presented at *the Computer Vision and Pattern Recognition Workshop, 2004, CVPRW'04.*

Ferrari, V., Tuytelaars, T., & Gool, L. V. (2004). Simultaneous object recognition and segmentation by image exploration. In *Proceedings of the 8th European Conference on Computer Vision*, Prague, Tcheque Republic, 40–54.

Gehler, P., & Nowozin, S. (2009). On feature combination for multiclass object classification. Paper presented at *the IEEE 12th International Conference on Computer Vision*, 2009.

Gervautz, M., & Purgathofer, W. (1990). A simple method for color quantization: octree quantization. In S. G. Andrew (Ed.), *Graphics gems* (pp. 287-293): Academic Press Professional, Inc.

Geusebroek, J. (2006). Compact Object Descriptors from Local Colour Invariant Histograms. *British Machine Vision Conference.*

Gevers, T., & Smeulders, A. W. M. (1999). Color-based object recognition. *Journal of Pattern recognition*, 32(3), 453-464.

Ghoshal, A., Ircing, P., & Khudanpur, S. (2005). Hidden Markov models for automatic annotation and content-based retrieval of images and video. Paper presented at *the Proceedings of the 28th annual international ACM SIGIR conference on Research and development in information retrieval.*

Goferman, S., Zelnik-Manor, L., & Tal, A. (2010). Context-aware saliency detection. *IEEE Conference on Computer Vision and Pattern Recognition.*

Gong, Y., Chuan, C. H., & Xiaoyi, G. (1996). Image indexing and retrieval using color histograms. *Multimedia Tools and Applications, 2*(1996), 133–156.

Griffin, G., Holub, A., & Perona, P. (2007). *Caltech-256 object category dataset.* Technical Report UCB/CSD-04-1366, California Institute of Technology.

Grubinger, M. (2007). *Analysis and Evaluation of Visual Information Systems Performance.* (PhD Thesis), Victoria University, Melbourne, Australia.

Guldogan, E. (2008). *Improving content-based image indexing and retrieval performance.* (Doctoral Dissertation), Tampere University of Technology.

Guttman, A. (1984). R-trees: A dynamic index structure for spatial search. *Proceedings ACM SIGMOD International Conference Management Data,* 47–57.

Hafner, J., Sawhney, H.S., Esquitz, W., Flickner, M., & Niblack, W. (1995). Efficient color histogram indexing for quadratic form distance functions. *IEEE Transaction on Pattern Analysis and Machine Intelligence, 17* (1995), 729–736.

Hanjalic, A., Lienhart, R., Ma, W.-Y., & Smith, J. R. (2008). The Holy Grail of Multimedia Information Retrieval: So Close or Yet So Far Away? *IEEE Proceedings, Special Issue on Multimedia Information Retrieval, 96* (4), 541-547.

Hartigan, J. A., & Wong, M. A. (1979). Algorithm as 136: A k-means clustering algorithm. *Journal of the Royal Statistical Society. Series C (Applied Statistics), 28*(1), 100-108.

He, X. (2004). Incremental semi-supervised subspace learning for image retrieval. Paper presented at *the Proceedings of the 12th annual ACM international conference on Multimedia.*

Hegazy, D., & Denzler, J. (2008). Boosting colored local features for generic object recognition. *Pattern Recognition and Image Analysis, 18*(2), 323-327.

Hoi, C.-H., & Lyu, M. R. (2004). A novel log-based relevance feedback technique in content-based image retrieval. Paper presented at *the Proceedings of the 12th annual ACM international conference on Multimedia.*

Hou, A. Lin, Zhao, L.-Q., & Shi, D.-C. (2010). Garment image retrieval based on multi-features. Paper presented at *the International Conference on Computer, Mechatronics, Control and Electronic Engineering (CMCE)*, 2010.

Howarth, P. D. (2007). *Discovering images: features, similarities and subspaces.* (PhD Thesis), University of London.

Huang, J., Kumar, S. R., Mitra, M., Zhu, W.-J., & Zabih, R. (1997). Image indexing using color correlograms. *Proceedings of Computer Vision and Pattern Recognition*,17–19 June, 762–768.

ImageCLEF. (2003). *The CLEF Cross Language Image Retrieval Track.* Retrieved from http://imageclef.org/.

Jacobs, C. E., Finkelstein, A., & Salesin, D. H. (1995). Fast multiresolution image Querying. Paper presented at *the ACM International Conference on Computer Graphics and Interactive Techniques (SIGGRAPH)*, Los Angeles, CA.

Jaswal, G., & Kaul, A. (2009). Content Based Image Retrieval – A Literature Review. *National Conference on Computing, Communication and Control (CCC-09)*, 198-201.

Jegou, H., Schmid, C., Harzallah, H., & Verbeek, J. (2010). Accurate image search using the contextual dissimilarity measure. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 32*(1), 2-11.

Jeon, J., Lavrenko, V., & Manmatha, R. (2003). Automatic image annotation and retrieval using cross-media relevance models. Paper presented at *the Proceedings of the 26th annual international ACM SIGIR conference on Research and development in informaion retrieval*.

Jiebo, L., & Crandall, D. (2006). Color object detection using spatial-color joint probability functions. *IEEE Transactions on Image Processing, 15*(6), 1443-1453. doi: 10.1109/tip.2006.871081

Jones, K. S., & van Rijsbergen, C. J. (1976). Information retrieval test collections. *Journal of documentation, 32*(1), 59-75.

Jouili, S., & Tabbone, S. (2012). Hypergraph-based image retrieval for graph-based representation. *Pattern Recognition, 45*(11), 4054-4068.

Kankanhalli, M. S., & Rui, Y. (2008). Application potential of multimedia information retrieval. In *Proceedings of the IEEE, 96*(4), 712-720.

Kaski, S., Kangas, J., & Kohonen, T. (1998). Bibliography of self-organizing map (SOM) papers:1981-1997. *Neural computing surveys, 1*(3&4), 1-176.

Khan, F. S., Rao, M. A., Weijer, J. V. D., Bagdanov, A. D., Vanrell, M., & Lopez, A. (2012). Color Attributes for Object Detection. *Twenty-Fifth IEEE Conference on Computer Vision and Pattern Recognition (CVPR 2012)*.

Kim, S., Park, S., & Kim, M. (2003). Central Object Extraction for Object-Based Image Retrieval. *CIVR 2003 : International Conference on Image and Video Retrieval*, Urbana Champaign, IL, 39-49.

Kiranyaz, S., Birinci, M., & Gabbouj, M. (2010). Perceptual color descriptor based on spatial distribution: A top-down approach. *Journal of Image and Vision Computing 28* (8), 1309–1326.

Kiranyaz, S., Birinci, M., & Gabbouj, M. (2012). *Perceptual Color Descriptors*. Foveon, Inc. / Sigma Corporation., San Jose, California, USA: Boca Raton, FL, CRC Press.

Ko, B., & Byun, H. (2002). Integrated region-based image retrieval using region's spatial relationships. Paper presented at *16th International Conference of Pattern Recognition*, 2002.

Krishnan, N., Banu, M. Sheerin, & Christiyana, C. Callins. (2007). Content Based Image Retrieval Using Dominant Color Identification Based on Foreground Objects. *Proceedings of the International Conference on Computational Intelligence and Multimedia Applications (ICCIMA 2007)*, 3, 190-194.

Kunttu, I., Lepistö, L., Rauhamaa, J., & Visa, A. (2003). Image correlogram in image database indexing and retrieval. *Proceedings of 4th European Workshop on Image Analysis for Multimedia Interactive Services*, London, UK, April 9-11, 88-91.

Kushki, A., Androutsos, P., Plataniotis, K. N., & Venetsanopoulos, A. N. (2004). Retrieval of images from artistic repositories using a decision fusion framework. *IEEE Transactions on Image Processing, 13*(3), 277-292.

Laaksonen, J., Koskela, M., & Oja, E. (2002). PicSOM-self-organizing image retrieval with MPEG-7 content descriptors. *IEEE Transactions on Neural Networks, 13*(4), 841-853.

Lee, S.-J., Lee, Y.-H., Ahn, H., & Rhee, S.-B. (2008). Color image descriptor using wavelet correlogram. *The 23rd International Technology Conference on Circuits/Systems, Computers and Communications (ITC-CSCC)*, 1613–1616.

Lee, Y. H., Lee, K. H., & Ha, H. Y. (2003). Spatial Color Descriptor for Image Retrieval and Video Segmentation. *IEEE Transaction on Multimedia, 5*(3), 358–367.

Leibe, B., Mikolajczyk, K., & Schiele, B. (2006). Efficient Clustering and Matching for Object Class Recognition. *Proceedings of the British Machine Vision Conference*, 789-798.

Leung, C. H. C., & Hibler, D. (1991). *Architecture of a Pictorial Database Management System.* Technical report, British Library Research, London, UK.

Leung, C. H. C., & Ip, H. (2000). Benchmarking for Content-Based Visual Information Search. *Fourth International Conference On Visual Information Systems (VISUAL'2000)*, Lecture Notes in Computer Science (LNCS), Springer, Lyon, France, 1929, 442–456.

Lew, M. S., Sebe, N., Djeraba, C., & Jain, R. (2006). Content-based multimedia information retrieval: State of the art and challenges. *ACM Transactions on Multimedia Computing, Communications, and Applications (TOMCCAP), 2*(1), 1-19.

Li, J., & Wang, J. Z. (2008). Real-time computerized annotation of pictures. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 30*(6), 985-1002.

Li, J., Wu, W., Wang, T., & Zhang, Y. (2008). One step beyond histograms: Image representation using markov stationary features. *Proceedings of the IEEE International Conference on Computer Vision and Pattern Recognition*, 1–8.

Li, J. (2005). A mutual semantic endorsement approach to image retrieval and context provision. Paper presented at *the Proceedings of the 7th ACM SIGMM international workshop on Multimedia information retrieval*.

Li, J., & Lu, B.-L. (2009). An adaptive image Euclidean distance. *Pattern Recognition, 42*(3), 349-357.

Li, R., Bhanu, B., & Dong, A. (2005). Coevolutionary feature synthesized EM algorithm for image retrieval. Paper presented at *the Proceedings of the 13th annual ACM international conference on Multimedia*.

Li, Y. (2005). *Object and Concept Recognition for Content-Based Image Retrieval.* PhD Thesis, University of Washington.

LiFang, Y., XiangLin, H., Rui, L., & Hui, L. (2012). An Effective Similarity Measurement Algorithm for Dominant Color Feature Matching in Image Retrieval. *Applied Mechanics and Materials, 182*, 1169-1173.

Lightstone, S., Teorey, T., & Nadeau, T. (2007). *Physical Database Design: The Database Professional's Guide to Exploiting Indexes, Views, Storage, and More.* Morgan Kaufmann Publishers.

Lin, Y.-Y., Liu, T.-L., & Chen, H.-T. (2005). Semantic manifold learning for image retrieval. Paper presented at *the Proceedings of the 13th annual ACM international conference on Multimedia*.

Liu, G.-H., & Yang, J.-Y. (2013). Content-based image retrieval using colour difference histogram. Pattern Recognition, 46(1), 188-198.

Liwei, W., Yan, Z., & Jufu, F. (2005). On the Euclidean distance of images. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 27*(8), 1334-1339. doi: 10.1109/tpami.2005.165.

Lloyd, S. P. (1982). Least Squares Quantization in PCM. *IEEE Transaction Information Theory, 28* (2), 129–137.

Long, F., Zhang, H., & Feng, D. D. (2003). Fundamentals of content-based image retrieval. In *Multimedia Information Retrieval and Management* (pp. 1-26). Springer Berlin Heidelberg.

Luoni, C. (2000). *Development of an Interface to a Database Storing the Features of a Multimedia Retrieval System.* License thesis (BSc), Computer Vision and Multimedia Laboratory at the University of Geneva, Geneva, Switzerland.

Ma, W. Y., & Manjunath, B. S. (1997). Edge flow: A framework of boundary detection and image segmentation. *Proceedings IEEE Conference Computer Vision Pattern Recognition*, 744–749.

Ma, W. Y., & Manjunath, B. S. (1997). Netra: A toolbox for navigating large image databases. *International Conference on IEEE Image Processing*, 1997, 568-571.

Ma, W. Y., & Manjunath, B. S. (1999). NeTra: A Toolbox for Navigating Large Image Databases. *Multimedia Systems, 7*(3), 184-198.

Ma, W. Y., & Zhang, H. J. (1998). Benchmarking of image features for content-based retrieval. In *Signals, Systems & Computers, 1998. Conference Record of the Thirty-Second Asilomar Conference on IEEE* (Vol. 1, pp. 253-257).

Ma, W. Y., Deng, Y., & Manjunath, B. S. (1997). Tools for texture/color based search of images. *Proceedings of SPIE Conference on Human Vision and Electronic Imaging II*, 3106 (1997), 496–507.

Maimon, O., & Rokach, L. (2005). *Data Mining and Knowledge Discovery Handbook.* Springer.

Malisiewicz, T., & Efros, A. A. (2007). Improving spatial support for objects via multiple segmentations. In *British Machine Vision Conference.*

Manjunath, B. S., Ohm, J. -R., Vasudevan, V. V., & Yamada, A. (2001). Color and texture descriptors. *IEEE Transaction on Circuits and Systems for Video Technology, 11* (June), 703–715.

Matas, J., Koubaroulis, D., & Kittler, J. (2000). *Colour Image Retrieval and Object Recognition Using the Multimodal Neighbourhood Signature.* D. Vernon (Ed.): ECCV 2000, LNCS 1842,Springer-Verlag Berlin Heidelberg, 48-64.

Mauro, J. (2008). *Oracle interMedia Managing Multimedia Content*. ORACLE, USA.

Mehyar, T., & Atoum, J. O. (2012). An Enhancement on Content-Based Image Retrieval using Colour and Texture Features. Journal of Emerging Trends in Computing and Information Sciences, 3(4).

Mejdoub, M., Fonteles, L., BenAmar, C., & Antonini, M. (2009). Embedded lattices tree: An efficient indexing scheme for content based retrieval on image databases. *Journal Visual Communivation Image Representation, 20*(2), 145-156.

Milanese, R. (1993). *Detecting Salient Regions in an Image: from Biological Evidence to Computer Implementation*. PhD Thesis, University of Geneva.

Moghaddam, H., & Saadatmand-Tarzjan, M. (2006). Gabor wavelet correlogram algorithm for image indexing and retrieval. *The 18th International Conference on Pattern Recognition, ICPR 2006*, 2, 925–928.

Mojsilovic, A., Hu, J., & Soljanin, E. (2002). Extraction of perceptually important colors and similarity measurement for image matching, retrieval, and analysis. *IEEE Transaction of Image Processing, 11*(11), 1238–1248.

Mojsilovic, A., Kovacevic, J., Hu, J., Safranek, R., & Ganapathy, K. (2000). Matching and retrieval based on the vocabulary and grammar of color patterns. *IEEE Transactions on Image Processing, 9*(1), 38–54.

Moosmann, F., Triggs, W., & Jurie, F. (2006). Randomized clustering forests for building fast and discriminative visual vocabularies. In *Neural Information Processing Systems (NIPS) Conference.*

Mustaffa, M. R., Ahmad, F., Mahmod, R., & Doraisamy, S. (2012). Multi-resolution Joint Auto Correlograms: Determining the distance function. Paper presented at *the International Conference on Information Retrieval & Knowledge Management.*

Müller, H., Marchand-Maillet, S., & Pun, T. (2002). The truth about corel-evaluation in image retrieval. In *Image and Video Retrieval* (pp. 38-49). Springer Berlin Heidelberg.

Müller, H., Michoux, N., Bandon, D., & Geissbuhler, A. (2004). A review of content-based image retrieval systems in medical applications-clinical benefits and future directions. *International journal of medical informatics, 73*(1), 1-24.

Müller, H., Müller, W., Squire, D. M., Marchand-Maillet, S., & Pun, T. (2001). Performance evaluation in content-based image retrieval: Overview and proposals. *Pattern Recognition Letters, 22*(5), 593-601.

Nagasaka, A., & Tanaka, Y. (1992). Automatic video indexing and full video search for objects. *Visual Database Systems II: Proceedings of the IFIP*, 113–127.

Neumann, D., & Gegenfurtner, K. R. (2006). Image retrieval and perceptual similarity. *ACM Transactions on Applied Perception (TAP), 3*(1), 31-47.

Nister, D., & Stewenius, H. (2006). Scalable Recognition with a Vocabulary Tree. Paper presented at *IEEE Computer Society Conference on Computer Vision and Pattern Recognition*.

Nölle, M., Rubik, M., & Hanbury, A. (2006). Results of the muscle cis coin competition 2006. Paper presented at *the Proceedings of the Muscle CIS Coin Competition Workshop*, Berlin, Germany.

Ortega-Binderberger, M., & Mehrotra, S. (2004). Relevance feedback techniques in the MARS image retrieval system. *Multimedia systems, 9*(6), 535-547.

Pass, G., & Zabih, R. (1999). Comparing images using joint histograms. *Springer. Multimedia Systems, 7*(3), 234-240.

Pauleve, L., Jegou, H., & Amsaleg, L. (2010). Locality sensitive hashing: A comparison of hash function types and querying mechanisms. *Pattern Recognition Letter, 31*(11), 1348-1358.

Pass, G., Zabih, R., & Miler, J. (1997). Comparing Images Using Color Coherence Vectors. *Proceeding ACM on Multimedia*, 65-73.

Pavlidis, T. (2008). Limitations of CBIR. *International Conference on Pattern Recognition*, December 8-11 in Tampa, Florida.

Pedronette, D. C. G., & Torres, R. D. S. (2012). Exploiting pairwise recommendation and clustering strategies for image re-ranking. *International Journal of Information Sciences*, *207*, 19-34.

Penatti, O. A., Valle, E., & Torres, R. D. S. (2012). Comparative study of global color and texture descriptors for web image retrieval. *Journal of Visual Communication and Image Representation*, *23*(2), 359-380.

Peng, J. (2003). Multi-class relevance feedback content-based image retrieval. *Computer Vision and Image Understanding*, *90*(1), 42-67.

Po, L. M., & Wong, K. M. (2004). A new palette histogram similarity measure for MPEG-7 dominant color descriptor. *IEEE International Conference Image Processing (ICIP'04)*, 3 (2004), 1533–1536.

Poursistani, P., Nezamabadi-pour, H., Askari Moghadam, R., & Saeed, M. (2013). Image indexing and retrieval in JPEG compressed domain based on vector quantization. Mathematical and Computer Modelling, 57(5–6), 1005-1017. doi: http://dx.doi.org/10.1016/j.mcm.2011.11.064.

Powell, G. (2006). *Beginning Database Design and Implementation.* Wrox Press.

Premchaiswadi, W., & Tungkasthan, A. (2011). A Compact Auto Color Correlation using Binary Coding Stream for Image Retrieval. *Proceedings of the 15th WSEAS international conference on Computers*, 430-436.

Qiu, G. (2003). Color Image indexing using BTC. *IEEE Transaction on Image Processing*, *12*(1), 93–101.

Rafiee, G., Dlay, S. S., & Woo, W. L. (2010). A review of content-based image retrieval. Paper presented at *the 7th International Symposium on Communication Systems Networks and Digital Signal Processing (CSNDSP)*, 2010.

Rahman, M. M. (2008). *Semantical Representation and Retrieval of Natural Photographs and Medical Images Using Concept and Context-based feature spaces.* Ph.D. Dissertation, Computer Science And Software Enggineering, Concordia University, Canada, 13-18.

Rahmani, R., Goldman, S. A., Zhang, H., Krettek, J., & Fritts, J. E. (2005). Localized content based image retrieval. Paper presented at *the Proceedings of the 7th ACM SIGMM international workshop on Multimedia information retrieval.*

Rasiwasia, N., Moreno, P. J., & Vasconcelos, N. (2007). Bridging the Gap: Query by Semantic Example. *IEEE Transactions Multimedia, 9*(1), 923-938.

Renato, O. S., Mario, A. N., & Alexandre, X. F. (2002). A Compact and Efficient Image Retrieval Approach Based on Border/Interior Pixel Classification. *Proceedings Information and Knowledge Management*, 102-109.

Rodhetbhai, W. (2009). *Preprocessing for Content-Based Image Retrieval.* (PhD Thesis), University Of Southampton.

Rubner, Y., Tomasi, C., & Guibas, L. J. (2000). The earth mover's distance as a metric for image retrieval. *International Journal of Computer Vision, 40*(2), 99-121.

Rui, Y., & Huang, T. (2000). Optimizing learning in image retrieval. Paper presented at *the IEEE Conference on Computer Vision and Pattern Recognition.*

Rui, Y., Huang, T. S., & Chang, S.-F. (1999). Image retrieval: Current techniques, promising directions, and open issues. *Journal of Visual Communication and Image Representation, 10*(1), 39-62.

Russell, B. C., Freeman, W. T., Efros, A. A., Sivic, J., & Zisserman, A. (2006). Using multiple segmentations to discover objects and their extent in image collections. Paper presented at *IEEE Computer Society Conference on the Computer Vision and Pattern Recognition*, 2006.

Rutishauser, U., Walther, D., Koch, C., & Perona, P. (2004). Is bottom-up attention useful for object recognition?. Paper presented at *the IEEE Conference on Computer Vision and Pattern Recognition*, 37–44.

Salton, G., & McGill, M. J. (1986). *Introduction to Modern Information Retrieval*. McGraw-Hill Inc., New York City, NY, USA.

Samet, H. (1990). *The Design and Analysis of Spatial Data Structures.* Reading, MA: Addison-Wesley.

Sande, K., Gevers, T., & Snoek, C. (2008). Evaluation of color descriptors for object and scene recognition. *IEEE Conference on Computer Vision and Pattern Recognition, CVPR*, 1–8.

Sande, K. E., Gevers, T., & Snoek, C. G. (2010). Evaluating color descriptors for object and scene recognition. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 32*(9), 1582-1596.

Schettini, R., Ciocca, G., & Zuffi, S. (2001). A survey of methods for colour image indexing and retrieval in image databases. *Color Imaging Science: Exploiting Digital Media*, 183-211.

Schmid, C., Mohr, R., & Bauckhage, C. (2000). Evaluation of interest point detectors. *International Journal of Computer Vision, 37(2)*, 151–172.

Sha'ashua, A., & Ullman, S. (1988). Structural saliency: the detection of globally salient structures using a locally connected network. *International Conference on Computer Vision (ICCV)*, 321-327.

Sikora, T. (2001). The MPEG-7 visual standard for content description-an overview. *IEEE Transactions on Circuits and Systems for Video Technology, 11*(6), 696-702.

Smeulders, A., Worring, M., Santini, S., Gupta, A., & Jain, R. (2000). Content-based image retrieval at the end of the early years. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 22*(12), 1349-1380.

Smith, J. R., & Chang. (1996). Visualseek: A Fully Automated Content-Based Image Query System. *Proceedings of ACM Multimedia*, Boston, 87-98.

Spath, H. (1980). *Cluster Analysis Algorithms for Data Reduction and Classification.* Ellis Horwood Publishers, England.

Stehling, R. de O., Nascimento, M. A., & Falcao, A. X. (2003). Cell histograms versus color histograms for image representation and retrieval. *Knowledge and Information Systems, 5*(3), 315–336.

Stehling, R. de O., Nascimento, M. A., & Falcao, A. X. (2001). An adaptive and efficient clustering-based approach for content-based image retrieval in image databases. *International Database Engineering & Applications Symposium*, 356–365.

Stricker, M. A., & Orengo, M. (1996). Similarity of color images. *Proceedings SPIE, Storage Retrieval Still Image Video Databases IV*, 2420, 381–392.

Sudhamani, M. V., & Venugopal, C. R. (2007). Grouping and indexing color features for efficient image retrieval. *International Journal of Applied Mathematics and Computer Sciences, 4*(3), 150-155.

Sudhamani, M. V., & Venugopal, C.R. (2006). Non-parametric classification of image data through clustering: An application for image Retrieval. *Proceedings of IEEE International Conference Image and signal processing*.

Swain, M., & Ballard, D. (1991). Color Indexing. *International Journal of Computer Vision, 7*(1), 11–32.

Sykora, D., Burianek, J., & Zara, J. (2003). Segmentation of black and white cartoons. *Conference on Computer Graphics*, 223-230.

Sykora, D., Burianek, J., & Zara, J. (2005). Sketching cartoons by example. *2nd Eurographics Workshop on Sketch-Based Interfaces and Modeling*, 27-34.

Tahaghoghi, S. M. M., Thom, J. A., & Williams, H. E. (2001). Are two pictures better than one? In *Australasian Database Conference*, Queensland, Australia, 138-144.

Talib, A., Mahmuddin, M., Husni, H., & George, L. E. (2013a). Efficient, Compact, and Dominant Color Correlogram Descriptors for Content-based Image Retrieval. Paper presented at *the MMEDIA 2013: Fifth International Conference on Advances in Multimedia*, Venice, Italy, 22-26 April 2013.

Talib, A., Mahmuddin, M., Husni, H., & George, L. E. (2013b). A weighted dominant color descriptor for content-based image retrieval. *Journal of Visual Communication and Image Representation, 24*(3), 345-360.

Talib, A., Mahmuddin, M., & Husni, H. (2010). Using content-based image retrieval for accessing images on the web for children. Paper presented at *the IEEE Second IITA International Joint Conference on Artificial Intelligence (IITA-JCAI 2010)*, 25-26 December , Shanghai, China.

Tao, D., Li, X., & Maybank, S. J. (2007). Negative samples analysis in relevance feedback. *IEEE Transactions on Knowledge and Data Engineering, 19*(4), 568-580.

Tao, D., Tang, X., Li, X., & Wu, X. (2006). Asymmetric bagging and random subspace for support vector machines-based relevance feedback in image retrieval. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 28*(7), 1088-1099.

Taranto, C., Mauro, N. D., Ferilli, S., & Esposito, F. (2010). Approximate image color correlograms. *Proceedings of the international conference on Multimedia*, Firenze, Italy, 1127-1130.

Taycher, L. (1997). *Image Feature Extraction Subsystem of the ImageRover WWW Image Search System.* Mater thesis, Boston University.

Thomée, B. (2010). *A picture is worth a thousand words: content-based image retrieval techniques.* (PhD Thesis), Leiden Institute of Advanced Computer Science (LIACS), Faculty of Science, Leiden University.

Tollari, S., & Glotin, H. (2007). Web image retrieval on ImagEVAL: Evidences on visualness and textualness concept dependency in fusion model. Paper presented at *the Proceedings of the 6th ACM international conference on Image and video retrieval*.

Tong, S., & Chang, E. (2001). Support vector machine active learning for image retrieval. Paper presented at *the Proceedings of the ninth ACM international conference on Multimedia*.

Torres, R., & Falcão, A. X. (2006). Content-based image retrieval: Theory and applications. *Journal of Theoretical and Applied Informatics (RITA), 13*(2), 161-185.

TRECVID. (2003). *TREC Video Retrieval Evaluation*. Retrieved from http://trecvid.nist.gov/.

Tungkasthan, A., Intarasema, S., & Premchaiswadi, W. (2009). Spatial color indexing using ACC algorithm. *7th International Conference on ICT and Knowledge Engineering*, 1-2 Dec. 2009, 113 – 117.

Tuytelaars, T., & Mikolajczyk, K. (2008). Local Invariant Feature Detectors: A Survey. *Foundations and Trends in Computer Graphics and Vision, 3* (3), 177-280.

Vailaya, A., Figueiredo, M. A. T., Jain, A. K., & Zhang, H. J. (2001). Image classification for content-based indexing. *IEEE Transactions on Image Processing, 10*(1), 117-130.

van de Weijer, J., Schmid, C., Verbeek, J., & Larlus, D. (2009). Learning Color Names for Real-World Applications. *IEEE Transactions on Image Processing, 18*(7), 1512-1523. doi: 10.1109/tip.2009.2019809

Vidal, M. L. A., Cavalcanti, J. M. B., de Moura, E. S., da Silva, A. S., & da Silva Torres, R. (2012). Sorted dominant local color for searching large and heterogeneous image databases. Paper presented at *the 21st International Conference on Pattern Recognition (ICPR)*.

Voorhees, E. M. (1998). Variations in relevance judgments and the measurement of retrieval effectiveness. Paper presented at *the Proceedings of the 21st annual international ACM SIGIR conference on Research and development in information retrieval.*

Voorhees, E. M., & Buckley, C. (2002). The effect of topic set size on retrieval experiment error. Paper presented at *the Proceedings of the 25th annual international ACM SIGIR conference on Research and development in information retrieval*.

Voorhees, E. M., & Harman, D. (2000). Overview of the sixth text retrieval conference (TREC-6). *Information Processing & Management, 36*(1), 3-35.

Wan, X., & Kuo, C.-C. J. (1996). Color distribution analysis and quantization for image retrieval. In *Security Professionals Information Exchange SPIE proceedings*, 2670.

Wan, X., & Kuo, C. J. (1998). A multiresolution color clustering approach to image indexing and retrieval. *Proceedings IEEE International Conferencec Acoustics, Speech, Signals Processing*, 6, 3705–3708.

Wang, C., Zhang, L., & Zhang, H. J. (2008). Learning to Reduce the Semantic Gap in Web Image Retrieval and Annotation. *The Annual International ACM SIGIR Conference on Research and development in information retrieval*, Singapore, 355-362.

Wang, J. Z., Li, J., & Wiederhold, G. (2001). SIMPLIcity: Semantics-sensitive integrated matching for picture libraries. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 23*(9), 947-963.

White, D. A., & Jain, R. (1996). Similarity indexing with the SS-tree. *Proceedings 12th IEEE Confernce on Data Engineering*, 516–523.

Williams, A., & Yoon, P. (2007). Content-based image retrieval using joint correlograms. *Multimedia tools and Applications, 34*(2), 239-248.

Wong, K. M., Po, L. M., & Cheung, K. W. (2007). A compact and efficient color descriptor for image retrieval. *Proceedings of IEEE International Conference on Multimedia and Expo (ICME 2007)*, Beijing, China, 611–614.

Wong, K.-M., Po, L.-M., & Cheung, K.-W. (2007). Dominant Color Structure Descriptor For Image Retrieval. *IEEE International Conference on Image Processing, 2007*, 6, 365-368.

Xia, W., & Kuo, C. C. J. (1998). A new approach to image retrieval with hierarchical color clustering. *IEEE Transactions on Circuits and Systems for Video Technology, 8*(5), 628-643. doi: 10.1109/76.718509

Yamada, A., Pickering, M., Jeannin, S., & Jens, L.C. (2001). *MPEG-7 Visual Part of Experimentation Model Version 9.0 - Part 3 Dominant Color*. ISO/IEC JTC1/SC29/WG11/N3914, Pisa.

Yanai, K., Shirahatti, N. V., Gabbur, P., & Barnard, K. (2005). Evaluation strategies for image understanding and retrieval. Paper presented at *the Proceedings of the 7th ACM SIGMM international workshop on Multimedia information retrieval.*

Yang, N.-C., Chang, W.-H., Kuo, C.-M., & Li, T.-H. (2008). A fast MPEG-7 dominant color extraction with new similarity measure for image retrieval. *Journal of Visual Communication and Image Representation, 19* (2008), 92–105.

Yi, T., & William, I. G. (1999). Spatial Color Indexing: A Novel Approach for Content-Based Image Retrieval. *Proceedings of International Conference on Multimedia Computing and Systems ICMCS*, 530 – 535.

Yi, T., & William, I. G. (2007). Content-based image retrieval using joint correlogram. *Multimedia Tools and Applications, 34*(2), 239-248, Springer.

Yildizer, E., Balci, A. M., Jarada, T. N., & Alhajj, R. (2012). Integrating wavelets with clustering and indexing for effective content-based image retrieval. *Journal of Knowledge-Based System, 31*, 55-66.

Yu, J., & Seah, H.-S. (2011). Fuzzy diffusion distance learning for cartoon similarity estimation. *Journal of Computer Science and Technology, 26*(2), 203-216.

Yu, J., Cheng, J., & Tao, D. (2012). Interactive cartoon reusing by transfer learning. *Journal of Signal Processing, 92*(9), 2147-2158.

Zagoris, K., Chatzichristofis, S. A., Papamarkos, N., & Boutalis, Y. S. (2009). img(Anaktisi): A Web Content Based Image Retrieval System. *International Workshop on Similarity Search and Applications*, 154-155.

Zhai, Y., & Shah, M. (2006). Visual attention detection in video sequences using spatiotemporal cues. *ACM Multimedia*, 815-824.

Zhang, H., Gong, Y., Low, C. Y., & Smoliar, S.W. (1995). Image retrieval based on color features: An evaluation study. *Proceedings of SPIE Digital Image Storage Archiving Systems*, 2606, 212–220.

Zhang, H., & Zhong, D. (1995). Scheme for visual feature-based image indexing. Paper presented at *the IS&T/SPIE's Symposium on Electronic Imaging: Science & Technology*.

Zhang, Jun. (2011). *Robust content-based image retrieval of multi-example queries.* (PhD Thesis), University of Wollongong.

Zhang, L., Lin, F., & Zhang, B. (2001). Support vector machine learning for image retrieval. Paper presented at *the International Conference on Image Processing*, 2001.

Zhang, M., & Alhajj, R. (2009). Content-Based Image Retrieval: From the Object Detection/Recognition Point of View. Book chapter in *Artificial Intelligence for Maximizing Content Based Image Retrieval*, 115-144.

Zhang, Q., & Tai, X. Y. (2008). Endoscope Image Retrieval Based on Color Feature Fusion. Paper presented at *the Congress on Image and Signal Processing, IEEE CISP'08*.

Zhang, S., Huang, J., Huang, Y., Yu, Y., Li, H., & Metaxas, D. N. (2010). Automatic image annotation using group sparsity. Paper presented at *the IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*.

Zhang, S., Yang, M., Cour, T., Yu, K., & Metaxas, D. (2012). Query Specific Fusion for Image Retrieval. *The 12th European Conference on Computer Vision (ECCV).*

Zhang, Y. (2002). *On The Use of CBIR in Image Mosaic Generation.* Technical Report, Dept. of Computing Science, University of Alberta, Edmonton, Alberta, Canada.

Zhou, X. S., & Huang, T. S. (2003). Relevance feedback in image retrieval: A comprehensive review. *Multimedia systems*, *8*(6), 536-544.

Zhou, Z.-H., Chen, K.-J., & Dai, H.-B. (2006). Enhancing relevance feedback in image retrieval using unlabeled data. *ACM Transactions on Information Systems (TOIS), 24*(2), 219-244.