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ZERNIKE MOMENTS-LOCAL DIRECTIONAL PATTERN FUSION FOR CONTENT-BASED FISH SPECIES IMAGE RETRIEVAL USING MOMENTGRAM AND HUE CHANNEL COLOUR SPACE

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By

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ZERNIKE MOMENTS-LOCAL DIRECTIONAL PATTERN FUSION FOR CONTENT-BASED FISH SPECIES IMAGE RETRIEVAL BASED ON MOMENTGRAM AND HUE CHANNEL COLOUR SPACE

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There is an increasing interest in the description and representation of fish species images. For that purpose, Content-based Image Retrieval (CBIR) is applied. Various techniques have been proposed for feature extraction to achieve good image representation and description result. One of them is the fusion of Zernike Moments (ZM) and Local Directional Pattern (LDP). ZM is rotation invariant and very powerful in extracting global shape feature, while LDP is texture and local shape feature extractor. However, existing works on ZM-LDP fusion are only used for gray-level images and are only invariant to rotation. While for fish images, colour plays an important role and the method should also be invariant to basic transformations such as rotation, translation, and scaling. This research proposes to improve the ZM-LDP method so that it will be able to extract colour features, be invariant to basic transformations, and further able to effectively represent the colour, shape and texture features for the fish-domain. The colour information property is obtained by computing the LDP on the Hue channel of the HSV colour space. The improved descriptor with colour information is tested on Fish4knowledge (natural image) image dataset consists of 27370 images and the proposed method has successfully achieved Mean Average Precision (MAP) of 77.62% and at the same time outperformed the other comparable methods. To achieve invariant to basic transformations, ZM-LDP fusion is improved by applying LDP on momentgram of the image. Retrieval experiment conducted on 27370 Fish4knowledge (mask image) image dataset have shown that the proposed method is able to achieve MAP of 91.3% and at the same time outperformed the other benchmark methods. These two proposed methods are then fused for content-based fish species image retrieval. Experiment is performed on 27370 Fish4knowledge (natural image) dataset, and the fused method has achieved MAP of 87.6%, which is higher than the benchmark methods. A statistical comparison

based on the Two-tailed paired *t*-test has also been conducted and the proposed fused method has shown a significant improvement in retrieval performance.

Keywords - content-based image retrieval; shape; colour; feature extraction; fish; local feature; global feature; invariant to rotation, scaling and translation; local directional pattern; zernike moment; momentgram;

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

DETIK-DETIK ZERNIKE-CORAK ARAH TEMPATAN YANG DIGABUNG UNTUK DAPATAN SEMULA IMEJ SPESIS IKAN BERASASKAN KANDUNGAN BERASASKAN MOMENTGRAM DAN RUANG WARNA SALURAN HUE

Oleh

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Perhatian yang diberikan berkenaan keterangan dan perwakilan spesis ikan telah meningkat. Bagi tujuan tersebut, Dapatan Semula Imej Berasaskan Kandungan (CBIR) digunakan. Pelbagai kaedah pengekstrakan ciri telah dicadangkan untuk mendapatkan hasil penerangan dan perwakilan imej yang baik. Salah satunya adalah gabungan Detik-detik Zernike (ZM) dan Corak Arah Tempatan (LDP). ZM adalah tidak dipengaruhi oleh putaran dan merupakan pengekstrak ciri bentuk global yang baik manakala LDP berkemampuan untuk mengekstrak ciri tekstur dan ciri bentuk lokal. Walau bagaimana pun, kerja yang telah dilakukan berkenaan gabungan ZM-LDP hanya terhad kepada imej kelabu dan hanya bebas daripada ciri transformasi putaran. Sedangkan bagi imej ikan, warna memainkan peranan yang penting, dan perlu mempunyai kriteria bebas dari pengaruh transformasi asas, seperti putaran, pembesaran dan translasi. Kajian ini mencadangkan untuk menambah baik gabungan ZM-LDP supaya ia berupaya mengekstrak ciri warna pada gambar, bebas dari pengaruh transformasi asas, dan seterusnya dapat mewakili ciri warna, bentuk dan tekstur dengan berkesan, khusus untuk domain ikan. Ciri warna adalah didapati dengan mengira LDP di saluran Hue daripada ruang warna HSV. Deskriptor LDP yang telah ditambah baik ini diuji pada set data imej *Fish4knowledge* (imej semula jadi) yang terdiri daripada 27370 imej dan kaedah yang dicadangkan mencapai Min Purata Ketepatan (MAP) 77.62%, dan pada masa yang sama berjaya mengatasi kaedah lain yang setanding. Gabungan ZM-LDP juga ditambah baik untuk menjadi bebas kepada perubahan transformasi asas. Untuk tujuan ini, kajian ini mencadangkan penggunaan LDP pada *momentgram* imej. Eksperimen yang dijalankan ke atas 27370 imej daripada *Fish4knowledge* (imej hitam putih) set data imej telah menunjukkan bahawa kaedah yang dicadangkan mampu mencapai MAP 91.3% dan pada masa yang sama mengatasi kaedah penanda aras yang lain. Kedua-dua kaedah yang dicadangkan kemudiannya digabungkan untuk membentuk dapatan semula imej berasaskan kandungan. Eksperimen ini dijalankan pada 27370 *Fish4knowledge* (imej semula jadi) set data imej, dan kaedah yang dicadangkan telah mencapai MAP 87.6%, iaitu lebih tinggi daripada kaedah penanda aras. Perbandingan statistik berdasarkan T*wo-tailed paired t-test* juga telah dijalankan dan kaedah gabungan yang dicadangkan telah menunjukkan peningkatan prestasi yang ketara.

Katakunci – dapatan semula imej berasaskan kandungan; bentuk; warna; pengekstrakan ciri; ikan; ciri lokal; ciri global; bebas dari pengaruh transformasi putaran, translasi dan pembesaran; corak arah tempatan; detik-detik zernike; momentgram;

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

CBIR	Content-based Image Retrieval
CH	Colour Histogram
FD	Fourier Descriptor
GM	Geometry Moments
HKs	Hermite Kernels
HLTC	Hough Line to Centroid Distance
HSV	Hue Saturation Value
LBP	Local Binary Pattern
LDP	Local Directional Pattern
LDPv	Local Directional Pattern with variance
MI	Moment Invariants
$pLDP^w$	LDP-weighted patches
$pWLDP^w$	Wavelet-based Shape-encoded Image with LDP-weighted patches
TBIR	Text-based Image Retrieval
TM	Tchebichef Moments
ULBP	Uniform LBP
QBIC	Query By Image Content
ZM	Zernike Moments
ZMInv	Zernike Moment Invariant
ZMHK	Zernike Moment Hermite Kernel
2D-DTCWT	2D Dual Tree Complex Wavelet Transform

CHAPTER 1

INTRODUCTION

1.1 Background

Developments in image capture device and photo sharing services such as Facebook and Instagram have resulted in a huge increase in the number of still images that are stored in digital format. The increasing number of images makes the process of image retrieval even more difficult. Hence, there is an awareness on the importance of managing and organising the collection of images systematically in databases. Images that are in the database can be retrieved through query. There are two types of query format, which are text-based and content-based (Liu, Zhang, Lu, and Ma, 2007).

Text-based Image retrieval (TBIR) has started since 1970s, where it uses textual caption as query (Ghosh, 2013). It is based on the idea of storing keyword, textual description or a set of keywords of the image content, created and entered manually by human annotators (Sheikh, Lye, Mansor, and Fauzi, 2011). To start the search, the user must enter the keywords related to the images. The system will find the image in the database that matches or is closest in meaning to the keywords entered. Using the right keywords are important to ensure the accurate image is being retrieved. If the user does not specify the right keywords, the desired image may be forever unreachable (Goyal, Walia and Brar, 2014).

Besides manually labelling large databases of images is not feasible or very expensive (Ghosh, 2013), this approach may also cause differences in human perception which leads to differences in image annotations. The implementation of automatic annotations has overcome this problem. However, automatic annotation is not always reliable. The annotations can be very subjective as image have different conditions, occlusions and complexity (Alkhawlani *et al.*, 2015). This can definitely contribute to retrieval inaccuracy. To overcome these disadvantages, researchers developed Content-based Image Retrieval (CBIR), a system that is capable to represent images based on its extracted content-based features, rather than utilising keywords or text descriptions (Goyal, Walia and Brar, 2014).

CBIR was introduced in the early 1980s (Liu *et al*., 2007) as an improvement to the TBIR (Sheikh, Mansor, Lye, and Fauzi, 2014). It is effective, efficient and able to extract low-level features such as colour, shape, and texture of the images automatically (Goyal and Walia, 2012). The systems aim to help and retrieve images based on their visual properties. The system will perform similarity measure to make comparison between the images features located in databases and the features of query image (Sheikh *et al*., 2011).

Technically, a typical CBIR system interpreted the images in the database and query image as a group of features. The relevant features between target images in databases and the query images are sorted after similarity measures are calculated. A lot of studies have been conducted and various kinds of CBIR systems have been developed including Query by Image Content (QBIC), Photobook, and VisualSEEk (Goyal and Walia, 2012). However, the extent to which the system is able to achieve accurate results is still an issue to be explored.

The performance of CBIR systems depend on the method of feature extraction, feature matching process and feature storage procedures (Spampinato *et al*., 2014). Feature extraction can be considered as one of the most important components in a CBIR system. This is because extraction of the wrong features may lead to irrelevant representation of the image characteristics. There are two types of features; low level features and high level features (Zarchi, Monadjemi, and Jamshidi, 2014). Information extracted from an image such as shape, colour, texture, spatial or any information that can be obtained from the image content itself are known as low level features while high level features is based on human perception or what the human thinks of the image. The way how computer and human interpret the images are different, and the interpretation gap is referred as 'semantic gap' (Liu *et al*., 2007).

The 'semantic gap' between those two types of features may affect the accuracy of the CBIR systems. Various methods and algorithms have been proposed in order to tackle this 'semantic gap' problem. Though a lot of experiments and studies have been performed, retrieval results of the existing CBIR systems are still far from user expectations, especially for specific domain.

Fisheries are receiving high attention and have become one of the main research topics recently (Ghosh, 2013). It is because fish plays an important role in our everyday life. They not only represent an important source of food and livelihoods, but also because of the human desire to know more about fish. The increasing number of fish population found makes them difficult to manage.

Staying informed regarding fish populations and examining their behaviour in a few unique circumstances is a task which sea life scientists battle with, due to the challenges in the accumulation of valuable information and typically used procedures that somehow modify the environment under observation (Kim and Kim, 2000).

There is small amount of CBIR developed specifically for fish domain. Fish lives in deep-sea underwater and has a streamlined body shape which allows it to move easily through the water with minimal frictional drag. The movements are not fixed to either horizontally or vertically. It is hard to capture fish images in proper position and lighting. Due to deep sea uncontrolled underwater environment, challenges of these images are low resolution and to be invariant to translation, rotation and scaling. The extraction of wrong features might lead to irrelevant representation. Even though it is a very important component of the CBIR system, but very few research has been done on feature extraction for fish domain. Present methods have largely been driven by commercial fish images, where images are of good quality (clear background and good illumination) captured in lab or in controlled environments (i.e., cameras, fixed background, lighting and objects in the water, and known number and types of fish). Apart from that, the types of dataset used in most of the previous works are also different from one another. Most of the previous works are focusing on different aspects (segmentation, feature extraction, semantic, fusion method). Due to this condition, it is important for the CBIR system for fish domain to be invariant to translation, scaling and rotation.

Shape is a vital visual feature for describing objects. There are six criteria which have been set for shape descriptor by MPEG-7. A good shape descriptor must have a hierarchical representation, good retrieval accuracy, general application, compact features, low computation complexity and robust retrieval performance (Singh and Sharma, 2013). Shape-based image retrieval can be categorised into two groups, which are contour-based shape descriptors and region-based shape descriptors (Goyal, Walia and Brar, 2014). They can further be divided into two types of features, which are global feature and local feature. The complexity of the shape of an object demands improvement on shape extraction techniques.

Image representation and description techniques gained a lot of attention in the last years where many researchers utilise these techniques in order to enhance the image retrieval field. The extraction of global features only or local features only might not be enough to achieve effective image representation. The fusion of global and local shape features is one of the approaches that can be used to overcome this problem.

Few researches on combining global and local shape features have been done. Some of the researches tested on the accuracy by comparing the results of global feature only, local feature only, and the combination of them. Experiments have shown that the combination of global and local features achieved higher retrieval accuracy compared to global feature only or local feature only (Goyal and Walia, 2012). Zernike moment is a powerful global shape feature extractor and LDP is able to extract local shape feature, and at the same time is not sensitive to illumination and noise (Goyal and Walia, 2012). For this reason, the combination of Zernike Moment (ZM) and Local Directional Pattern (LDP) is believed to be suitable for extracting the global and local shape features of fish images.

Depending only on one feature for image retrieval usually is less effective for achieving high accuracy. Colour is the dominant visual feature of any image and fish images are rich in colour. Therefore, there are a lot of studies focusing on combining shape and colour features for image retrieval.

1.2 Problem Statement

Various techniques have been used for developing feature extraction to achieve good representation and description results. Some of them gave good performance for specific domain or type of images but not for other domain or type of images. The combination of ZM and LDP are very effective and achieved good retrieval results (Goyal and Walia, 2012; Goyal, Walia, and Brar, 2014). ZM is very effective as global shape feature extractor and the criterion of magnitude of ZM is rotationally invariance. The advantages of LDP are the ability to extract both local shape feature and texture feature (Honglei Xu, and Kok Lay Teo, 2014; Luo *et al.*, 2016; Kumar *et al.*, 2016). LDP operator calculates the edge response values in different directions and uses these values to encode the image texture. Since the edge responses are less sensitive to illumination and noise than intensity values, so the LDP features can describe the local primitives, including different types of curves, corners and junctions in a more stable manner and also retain more information.

However, previous works on combining ZM and LDP are only utilised for gray level images. They were not used for extracting features from coloured images due to their deficiency in dealing with various lighting and viewing conditions of real-world scenes. While for fish image, colour feature can play an important role. It is one of the most widely used in image retrieval due to its compact representation and low computational complexity (Honglei Xu and Kok Lay Teo, 2014). In addition, image retrieval for fish should handle the invariant to rotation, scaling and translation as fish appears in a variety of scales, orientations, and body poses (Nery *et al*., 2005; Gosh, 2013). The previous combination of ZM and LDP however only tackle the rotation property.

1.3 Research Objectives

The objectives of this research are as follow:

1. To extend the ZM-LDP method so that it will be able to extract colour information.
2. To improve the ZM-LDP method to be invariant to translation and scaling.
3. To integrate the methods mentioned in objective (1) and (2) above for content-based fish species image retrieval. The integrated method is able to represent colour, shape, and texture features, and be invariant to rotation, scaling and translation.

1.4 Scope of Research

This research focuses on developing a CBIR system specifically for fish domain. The existing ZM-LDP is improved to be able to extract colour feature and be invariant to rotation, scaling and translation which contribute to a higher retrieval result. LDP is applied on Hue plane of HSV colour space of the images to extract colour feature.

To achieve invariant to rotation, scaling and translation properties for images, LDP is applied on momentgram instead of the original image. Momentgram is extracted from Zernike Moment Invariant (ZMInv).

The proposed descriptors are then fused to develop the prototype CBIR system specifically for fish images. The retrieval effectiveness of the prototype system is compared to some benchmark methods based on few retrieval effectiveness measurements such as Average 11 Standard Precision-Recall, Mean Average Precision (MAP) and Two-tailed paired *t*-test.

There are two types of dataset used. For colour descriptor, Fish4Knowledge (natural images) is used while for shape descriptor, Fish4knowledge (mask images) is used. As for overall performance of the proposed CBIR system for fish, Fish4knowledge (natural image) dataset is used. Both datasets consist of 27370 images with 23 categories.

The system will generate the Average 11 Standard Precision-Recall graph and MAP value for the selected queries and Average precision value for each groups. Statistical comparison based on the Two-tailed paired *t*-test has also been conducted to show the significance difference between the proposed method with the benchmark methods. The focus of this work is to improve the effectiveness of the system, therefore the computation time is not measured or discussed.

1.5 Research Methodology

Quantitative experimental approach is adapted as research methodology. First, the hypothesis, objective and goal of the experiment are defined. What has been done on CBIR for fish are reviewed. The particular colour and shape descriptors are critically reviewed which can be further improved to increase the retrieval accuracy.

The framework of the proposed system, including data dictionary, hardware requirements and software requirements are then designed. The threats to the experiment are evaluated.

After that, all of the proposed and benchmark methods are implemented in the CBIR prototype system. The retrieval effectiveness for each methods and measurements is collected and recorded. The results are tabulated in graphs and tables depending on necessities. The results are then discussed and recorded in the thesis.

1.6 Contributions of the Research

In this research, ZM-LDP descriptor is extended so that it will be able to extract colour information and at the same time able to be invariant to rotation, scaling and translation. The improvements made to the method is then applied for the retrieval of fish species images. The effectiveness of the proposed descriptor is compared with few related benchmark methods based on specific dataset and few standard retrieval effectiveness measurements.

The detail of the contributions of this research are as follow:

1. Extend the ZM-LDP fusion to be able to extract colour feature of the images. LDP descriptor is applied on Hue plane of HSV colour space of the image. The comparison between the proposed method with few benchmark methods show that the proposed descriptor achieved higher retrieval accuracy.
2. Improve ZM-LDP fusion to be invariant to scaling and translation. Instead of original images, LDP descriptor is applied on new image representation called momentgram. The retrieval performance of the proposed method is then compared to the other benchmark methods, and the results show that the proposed descriptor achieved higher retrieval result.
3. The proposed descriptors are then fused and applied to CBIR for fish species domain. Compared to benchmark methods, the proposed method achieved higher retrieval accuracy.

1.7 Thesis Organisation

There are seven chapter all together in this thesis. Chapter One is the introduction on the research works. It discusses about the background of the research, the problem arises from the benchmark methods that lead this research to be conducted, the objective of the research, the scope of the research, the methodology used to conduct this research and finally the contributions of this research.

Chapter Two provides a review about the literature work done by other researchers on the CBIR field in general and then focusing on related field. This chapter discusses deeply on feature extraction methods based on colour, shape and texture features, existing methods with invariant to rotation, scaling and translation property and previous CBIR developed for fish domain.

Chapter Three discusses about the methodology used to conduct this research. This chapter also covered the hardware and software requirements, data collection and analysis, evaluation measurement and experimental setting of each experiment conducted.

Chapter Four discusses in detail about the system framework, process flow charts, data dictionary, example of CBIR inputs and outputs and results and discussion of the EZLH (ZM+LDP+HLDP) as colour descriptor.

Chapter Five discusses in depth about the system framework, process flow charts, data dictionary, example of CBIR inputs and outputs and results and discussion of the ZMInvLDP, which is now invariant to scaling and translation.

Chapter Six discusses about the system framework, process flow charts, data dictionary, example of CBIR inputs and outputs and results and discussion of the IZLH (ZMInv+LDP+HLDP) for content-based fish species image retrieval. The comparison results and analysis between the proposed method with existing CBIR for fish species are also presented and discussed in this chapter.

Chapter Seven provides the summary of the work as well as the strengths and limitations of the proposed method. Future works on improving the proposed method is also suggested in this chapter.

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