Multi-spectral Remote-sensing Colour Image Retrieval Based on a Full Range Gaussian Markov Random Field Model

Final Technical Report of Major Research Project Submitted to the University Grants Commission, New Delhi

(F. No. 42-145/2013(SR) Dated 14.03.2013)

ज्ञान-विज्ञान विमुक्तये
University Grants Commission

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(K. SEETHARAMAN)
Principle Investigator

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FINAL REPORT OF THE WORK DONE ON THE MAJOR RESEARCH PROJECT

(2013 – 2017)

1. PROJECT REPORT No.: Final
2. UGC REFERENCE NO: F. No. 42-145/2013(SR)
3. PERIOD OF REPORT: April 1, 2013 to March 31, 2017
4. TITLE OF RESEARCH PROJECT: Multi-spectral Remote-sensing Colour Image Retrieval Based on A Full Range Gaussian Markov Random Field Model

4 (a) NAME OF THE PRINCIPAL INVESTIGATOR: Dr. K. SEETHARAMAN

(b) DEPARTMENT: Computer and Information Science

(c) UNIVERSITY WHERE WORK HAS PROGRESSED: Annamalai University

5 EFFECTIVE DATE OF STARTING OF THE PROJECT: April 1, 2013

6 GRANT APPROVED AND EXPENDITURE INCURRED DURING THE PERIOD OF THE REPORT:

a. TOTAL GRANT APPROVED: Rs. 10,40,800/-

b. TOTAL GRANT RELEASED: Rs. 9,21,580/-

c. REPORT OF THE WORK DONE: Please refer to **ANNEXURE II**

i. Brief objective of the project

ii. Work done so far and results achieved and publications, if any, resulting from the work

iii. (Give details of the papers and names of the journals in which it has been published or accepted for publication)

iv. Has the progress been according to original plan of work and towards achieving the objective: **YES**

v. Please indicate the difficulties, if any, experienced in implementing the project. No.

vi. If the project has been completed, please enclose a summary of the findings of the study. One bound copy of the final report of work done may also be sent to University Grants Commission.

vii. Any other information which would help in evaluation of work done on the project. At the completion of the project, the first report should indicate the output, such as (a) Manpower trained (b) Ph. D. awarded (c) Publication of results: Please refer to **ANNEXURE I**

ANNEXURE-I

PROFORMA FOR SUBMISSION OF INFORMATION AT THE TIME OF SENDING THE FINAL REPORT OF THE WORK DONE ON THE PROJECT

1. Title of the Project: Multi-spectral Remote-sensing Colour Image Retrieval Based on A Full Range Gaussian Markov Random Field Model
2. Name and address of the Principal Investigator: Dr. K. Seetharaman, Department of Computer & Information Science, Annamalai University, Annamalainagar 608 002, Tamil Nadu.
3. Name and Address of the Institution: Annamalai University, Annamalainagar 608 002, Tamil Nadu.
4. UGC Approval Letter No. and Date: 42-145/2013(SR) date: 14.03.2013
5. Date of Implementation: 12.06.2013
6. Tenure of the Project: March 2013 – March 2017
7. Total Grant Allocated: Rs. 10,40,800/-
8. Total Grant Received: Rs. 9,21,580/-
9. Final Expenditure: Rs. 9,21,580/-
10. Objectives of the Project: Please refer to **ANNEXURE II**
11. Whether Objectives were Achieved: **YES**. Please refer to **ANNEXURE II**
12. Achievements from the Project: Please refer to **ANNEXURE II**
13. Summary of the Findings: Please refer to **ANNEXURE III**
14. Contribution to the Society: Please refer to **ANNEXURE III**
15. Whether any Ph.D. Enrolled/Produced out of the Project: **Yes** (one). But, he has discontinued in the middle of the period because he has got job in banking sector.
16. No. of Publications out of the Project: **Five** (Please refer to **Annexure IV**)

ANNEXURE II

REPORT OF THE WORK DONE

BRIEF OBJECTIVES OF THE PROJECT

- The main objective of the project is to construct a system for effective retrieval of the Multi-spectral satellite imageries from the heterogeneous group of imageries.

To achieve the above objective, the following image processing methods have been carried out. These are the substance outcome of the project work.

- **Imagery Segmentation:** Segregates the Structure, Micro-structure, and Texture components separately from the multispectral satellite imageries.
- **Feature Extraction:** Introduction of a novel feature extraction method, based on stochastic model and Bayes-based Back-propagation Deep Learning method.
- **Deep Learning Neural Network:** Construction of A Bayes-based Back-propagation Deep Learning Network, based on Bayes rule probabilistic distribution concepts.

OBJECTIVES DONE ON THE PROJECT

1. Introduction

The proliferation of wide range of applications of satellite imageries in various fields, traffic management and road monitoring, water resource management, agriculture, geographical information and mapping, defence, urban development, meteorology, forest departments and so on, has turned the attention of the research community of computer vision to develop advanced techniques, which assist swift manipulation of image processing methods like classification, enhancements, compression, matching and retrieval, etc. Owing to complex structure of the satellite imagery and the requirement of large amounts of space to store them, it necessitates developing an effective and efficient retrieval method. Literature reveals that either point-processing or mask-processing methods have been used for digital image processing. The point-processing-based techniques could not work well for high-spatial resolution imageries because of the high-frequency components and horizontal layover caused by off-nadir look angles. So, it leads to misclassification, and results salt and pepper effects. The literature reveals that object-based method yields better results than the point-processing methods, which subdivides an image into meaningful homogeneous regions, based on not only spectral properties but also on shape, texture, size, and other topological features and organizes them hierarchically as image objects. But there are some difficulties in the segmentation of remotely sensed imageries like forest areas, roads and buildings in residential areas, and cultivated crops in agricultural lands. Yang and Newsam have performed an extensive evaluation of local invariant features (LIF) for imagery retrieval of land-use/land-cover (LULC) classes with high-resolution aerial imagery, and have compared the standard features, color and texture. They have reported that the local invariant features yield good results. Aptoula has applied global morphological texture descriptors (GMTF) for retrieving the remote sensing images. He, also, has used the multiscale texture descriptors, called, circular covariance histogram and rotation-invariant point triplets. Moreover, he introduces a couple of new descriptors, exploiting the Fourier power spectrum of the quasi-flat-zone-based scale space of their input. Du et al. have proposed a method, based on structural information, which mainly contributes on: (i) mapping the features into a manifold space by a Lipschitz smooth function to enhance the representation ability of the features; (ii) training an anchor set with several regularization constrains to get the intrinsic manifold structure. Bosilj et al. have proposed morphological descriptors known as pattern spectra (PS). They are computationally efficient histogram-like structures describing the global distribution of arbitrarily defined attributes of connected image components. Li et al. have proposed a method, based on deep convolutional neural network (CNN) model, which extracts deep features region-wise. They, also, encode the extracted regional deep features by an improved Vector of Locally Aggregated Descriptors (VLAD) algorithm to generate feature representation for the imageries. They suggest that the features extracted region-wise yield better results than the features extracted globally. This paper believes that this methodology could be appropriate for normal structural images, but not for remote sensing imageries. Because most remote sensing imageries contain texture-like structures rather than the proper structures (objects/shapes). Napoletano reports that content of the remote sensing images might be quite heterogeneous, which ranges from fine grained textures to coarse grained ones or to images containing objects. Also, he suggests that it is not obvious which descriptor should be employed to describe images having such a variability. Further, he suggests that whatever is the retrieval scheme adopted, CNN-based descriptors are more effective than the local descriptors in the case of the LandUse dataset wheras less effective than the local-based descriptors in the case of the SceneSat dataset. Liu et al. have proposed a method, based on the colors with microstructure descriptors of similar edge orientation. The microstructures integrate color, texture, shape, and color layout information together for image retrieval, which has the advantages of both statistical and structural texture description approaches. They claim that the algorithm has high indexing performance with low dimensions.

In this paper, it is believed that the structure, microstructure and texture components play a noteworthy role in remote sensing imagery retrieval. Because the multispectral satellite imagery contains texture-like structure and microstructure properties. Thus, the micro-level structure properties could be very useful to match and retrieve the target imagery. This motivated to develop the proposed method.

The literature reveals that the ANN plays a noteworthy role in parameter estimate. Si and He have applied an ANN technique to estimate the parameters of the autoregressive model and reported, the ANN-based parameter estimate yields better results than the maximum likelihood and Bayes methods. Wang et al. have proposed a method, which pairs patches from key and reference images, and then learn the mapping directly between these patch-pairs and their matching labels for image registration. Rezende et al. have introduced a recognition model, which represents an approximate posterior distribution and used for optimization of a variational lower bound. In addition, they have developed a stochastic backpropagation rule for gradient backpropagation through stochastic variables and derived an algorithm that allows joint optimization of the parameters of both the generative and recognition models. Thus, this project work applies a combination of AGMRF model and Bayes-based Backpropagation Deep Learning (BBDL) network to estimate the parameters of the AGMRF model. The BBDL network results a better estimate of the parameters, whilst it requires a bit high computational time than the traditional Bayesian method. However, the computational time complexity is negligible while considering the need of the precise parameter estimate. The precise parameter estimate could refine the segregation of the structure, microstructure, and texture components; so as to it leads a better retrieval result.

Achievements from the Project

- An imagery database has been constructed with more than 1400 imageries collected from various sources of satellite imagery datasets, such as IKONOS, LULC, SPOT 6 HRG, SPOT Vegetation, Landsat 7, TM/ETM+, and MODI Land cover. Features extracted from the imageries and a feature vector database has been constructed. A link has been established between the imageries in the imagery database and the corresponding feature vectors of the feature vector database, which facilitates the proposed system for fast retrieval.
- A Bayes-based Backpropagation Deep Learning (BBDL) method has been constructed.

- The proposed method segregates structure, microstructure, and texture components of the imageries, and extracts features from each component individually with high precision.
- The obtained results were compared with the state-of-the-art methods, which shows that the proposed method outperforms the state-of-the-art methods.

Thus, the microstructure component not only integrates the color, texture, shape, and color layout together as a whole information for image retrieval as discussed in [9], but it acts as a trade-off between the structure and texture components in the object/shape formation. Hence, the features extracted individually from structure, microstructure, and texture components play a significant role in imagery retrieval, especially the microstructure features. Hence, the proposed method is most appropriate for multispectral satellite imagery retrieval because the satellite imageries are formed at the micro-level with the help of different homogeneous or similar shapes. Because of the multispectral imageries are captured through satellite from millions of kilometers, even the very big objects/shapes (a large buildings, trees, water tanks, etc. in Fig. 3) seem to be a tiny one. Despite the satellite imageries seem to be a texture, actually, they are structured imageries with a large number of objects/shapes.

ANNEXURE III

SUMMARY OF THE FINDINGS

The proposed Adaptive Gaussian Markov Random Field (AGMRF) model and the Bayes-based Backpropagation Deep Learning (BBDL) method were implemented with manifold multispectral satellite imageries. The satellite imagery was segregated into structure, microstructure, and texture components individually. The features extracted from each component were compared with the features in the feature database using the Jeffrey's divergence (JD) measure and the histogram-based similarity measure. If the query and target imageries pass the tests, then it is marked and ranked. The average normalized modified retrieval rank (ANMRR) measure was applied to measure the performance of the proposed method, and the retrieval results show that the proposed method outperforms the existing methods in terms of precision and computational time complexity. The attained results of the empirical study of the project work are summarized below.

The experimental results illustrate the individuality and significance of the microstructure component, which notably contributes to multispectral imagery retrieval. The histogram method illustrates that the microstructure component exactly exposes the difference between the imageries and within the imagery at the micro-level. The microstructure components bridge the texture and structure components. The histograms of the microstructures evidence this. Thus, in the case of multispectral satellite imagery, the microstructure plays a noteworthy role in the formation of the shape of an imagery.

The structure component describes the overview of the objects/shapes in an imagery, while the texture component gives an absolute shape to the object with color. For instance, aerial panorama of the Rome city in Fig. 3, the structure component characterizes the overview of the Colosseum in the city while the microstructure component characterizes the tiny parts (buildings, passage, Gardens, water tanks, etc. inside of the Colosseum) of the Colosseum at micro-level. Thus, the microstructure component not only integrates the color, texture, shape, and color layout together as a whole information for image retrieval as Bosilj et al. reported, but it acts as a trade-off between the structure and texture components in the object/shape formation. Hence, the features extracted individually from structure, microstructure, and texture components play a significant role in imagery retrieval, especially the microstructure features. Hence, the proposed method is most appropriate for multispectral satellite imagery retrieval because the satellite imageries are formed at the micro-level with the help of different homogeneous or similar shapes. Because of the multispectral imageries are captured through satellite from millions of kilometers, even the very big objects/shapes (a large buildings, trees, water tanks, etc. in Fig. 3) seem to be a tiny one. Despite the satellite imageries seem to be a texture, actually, they are structured imageries with a large number of objects/shapes.

Thus, in the case of multispectral satellite imagery retrieval, the microstructure component yields better results than the other existing methods, and it performs better than the structure and texture components. In addition to the above results, the following results have been attained from the empirical study of the project work.

Contribution to the Society

The societal benefits of outcome of this project are high and a few of them listed below.

- The multi-spectral satellite imagery analysis, especially imagery retrieval plays a noteworthy role in various fields, such as traffic management and road monitoring, water resource management, agriculture, geographical information and mapping, defense, urban development, meteorology, forest departments and so on.
- It is very useful for fast retrieval of the satellite images from the repository. For example,
- The proposed image retrieval method could be used to retrieve a particular fruit or vegetable or a particular region of crop imagery from the satellite image database.
- It can be employed to track and retrieve a vehicle from a traffic management database system.
- It can be used to track, identify, and retrieve the rocket or any other defense vehicle of the enemy by the defense department. Likewise, we can list a numerous application of satellite image retrieval in various domains.

It is very useful for meteorology department to identify and predict the cyclone and weather forecasting.

A. Conclusion and Future Work

The proposed AGMRF model and the BBDL method were implemented with a manifold multispectral satellite imageries. The satellite imagery was segregated into structure, microstructure, and texture components individually. The features extracted from each component were compared with the features in the feature database using the methods discussed in Section V. If the query and target imageries pass the tests, then it is marked and ranked. The ANMRR measure was applied to measure the performance of the proposed method, and the retrieval results show that the proposed method outperforms the existing methods in terms of precision and computational time complexity. Because of the existence of the texture components in all kinds of imageries, which do not effectively distinguish the query and target imageries compare to the microstructure components. Thus, in the case of multispectral satellite imagery retrieval, the microstructure component yields better results than the other existing methods, and it performs better than the structure and texture components.

Reference

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ANNEXURE IV

NUMBER OF PAPERS PUBLISHED OUT OF THE PROJECT

Journal Papers

- **K. Seetharaman** and W.T. Chembian, Color Image Retrieval Based on Adaptive Statistical Distance Measure with Local Features, Pattern Recognition Letters, (*Elsevier*, ISSN: 0167-8655; **Impact Factor:** 1.995). (Accepted for publication).

- **K. Seetharaman** and S. Selvaraj, Statistical Tests of Hypothesis-Based Color Image Retrieval, *Journal of Data Analysis and Information Processing*, Vol. 4(2), pp. 90-99, May 2016 (ISSN: 2327-7211; **Impact Factor:** 1.04).

- **K. Seetharaman**, Image Retrieval Based on Micro-level Spatial Structure Features and Content Analysis Using Full Range Gaussian Markov Random Field Model, *Engineering Applications of Artificial Intelligence*, Vol. 40, pp. 103-116, April, 2015 (*Elsevier* –DOI:10.1016/j.engappai.2015.01.008; ISSN: 0952-1976; **Impact Factor**: 2.604).

International Conference Papers

- **K. Seetharaman** and W. T. Chembian, Statistical Distribution-Based Color Image Retrival, *International Conference on Graphics and Signal Processing* (ICGSP2017), Nanyang Technological University, Singapore, from 24.06.2017 to 28.06.2017, 2017, *ACM Digital Library* 2017, pp. 6–9 (ISBN: 978-1-4503-5239-0).

- **K. Seetharaman** and W. T. Chembian, Multi-spectral Satellite Color Image Retrieval Based on GMRFM and Back-propagation Algorithm with Artificial Neural Network, *International Symposium on Electronics and Smart Devices (ISESD 2016) Organized by the IEEE Section, Bandung, Indonesia on November 29-30, 2016*, Published in *IEEE Xplore,* 2016, pp. 278 – 282(ISBN: 978-1-5090-3841-1).