Vehicle detection in Satellite Imagery using Maximally Stable Extremal Regions

Shahid Karim†, Imtiaz Ali Halepoto††, Adnan Manzoor†††, Nazar Hussain Phulpoto††††, Asif Ali Laghari†††††

†,†††††Harbin Institute of Technology, China
†† Department of Computer Systems Engineering, QUEST Nawabshah, Pakistan
†††,†††† Department of Information Technology, QUEST Nawabshah, Pakistan

Summary
Vehicle detection has a huge contribution in the field of remote sensing and satellite imagery has been used in several applications of remote sensing such as traffic surveillance, object tracking, earth observation, and development planning. The low resolution images and poor visual of object is significant issue satellite imagery. To make an important contribution towards remote sensing application, we have examined Maximally Stable Extremal Regions (MSERs) for vehicle detection in satellite imagery. Sorting of extremal regions and intensity variation has an important role in detection. The MSER regions have been reduced on basis of region area. The evaluation of experiment provides a remark that MSER is very useful for vehicle detection application.

Key words:
Vehicle detection, Satellite imagery, MSERs, Remote sensing

1. Introduction

Satellite has been getting involved in recent worldwide applications since two decades. The satellite images are beneficial for several remote sensing applications and these images have been used for several purposes such as object detection, image analysis, aerial photography, image classification and spectral & spatial analysis of images. Day by day all these applications are being improved by researchers to make the computations faster and optimal. The proposed methods regarding vehicle detection are promising in current ongoing research due to effective computations, feature map utilization, multi-instance learning, sensors combination, superpixel segmentation and so on [1-5]. Satellite imagery has very low resolution as compared to ground based imagery. Mainly there are four kinds of resolutions in satellite imagery which has been already discussed such as; spatial, spectral, temporal and radiometric. Pixel values, wavelength intervals, amount of time and brightness; each property has been evaluated according to application. Spatial resolution is very much involved in region based application as interpretation of pixel values by optimal use of thresholding. Dealing of low resolution needs keen intension for experiment.

Region based image processing is also an efficient work to dealt with detection, recognition and classification problems. This processing further divided into many applications for example; feature matching, key point extraction, navigation, indexing and retrieving desired information from images. Detection through interest point is basic task in the field of image processing as well as detection through local features. Interest points are meaningful for detection and have stable and invariant properties. These interest points can also be called as regions of interest (ROIs) which provide accurate structural, shape and color information in an image. Object recognition is one of the ancient approaches which have been used for the recognition of several types; such as character recognition, object recognition and pattern recognition. Region based object recognition also has a huge contribution in the field of computer vision. Dependent shape of distinct regions has been detected robustly by using affine construction of these regions and affine frames have been established. The matching of these aligned frames and their color intensities have been used for comparison [6]. Another real time object recognition approach has been implemented for the complex environment where shape, texture or area of target object is not clear or blurred from the viewing place (occlusions, clutters). Average time for decision has been minimized by using visual memory for the purpose of real-time processing [7].

Recently many algorithms have been developed for the purpose of detection which works on the basis of interest points. Furthermore their assessment and association has been provided by several researchers. The previous effort for comparative study makes the implementation easier for detection by using local descriptors [8]. Among these interest point algorithms, Maximally Stable Extremal Region (MSER) is optimally works for extracting distinctive regions [6, 8, 9, 10]. MSERs work on the basis of intensity evaluation of under observation regions and their outer boundaries and pops up the regions of interests.

Manuscript received April 5, 2018
Manuscript revised April 20, 2018

In [10] author introduced extremal regions in image and their transformations of coordinates and intensities. This is specified for subset of extremal regions with affine invariant stability. Also there is robust experiment proposed for similarity measurement from their invariants which describe the correspondences between multiple regions. The pixels have two kinds of information, bright regions and dark regions, in MSER these regions are known as bright extremal regions and dark extremal regions. This division of regions has been placed according to their intensities values. High intensity and low intensity values represents bright and dark regions respectively. The thresholding process is used for the purpose of maximal stability in MSERs. Distinguished regions or connected components of objects have been fairly extracted by using thresholding [8]. The importance of feature extraction methods has been evaluated on basis of number of features and processing speed of method as well [11]. The MSER has also been utilized for detection of scene elements and proposed method has been used in robots to locate the targets [12].

This paper presents the main contribution of the vehicle detection using MSERs. Vehicles have been accurately detected by effective use of intensity variations. Firstly, the test image has been exploited according to the working principle of MSER to avoid false detection rate. The second consideration of MSER is the interpretations of minimum distance of distinguish regions. The detection accuracy has been enhanced by precise distance evaluation. Sorting of connected components is also an important parameter for detection using MSERs.

Rest of paper has been distributed as follows. In section 2 we have been briefly explained the working principle of our experiment. Section 3 describes the results and discussion of our experiment. Conclusion and future work has been discussed in section 4.

2. Methodology

In our methodology, we have implemented MSER based approach for the purpose of vehicle detection in satellite images. Although MSER works on the basis of intensity regions and it can be implemented on satellite imageries but lighting effects can vary the intensity values. Extremal regions have been briefly defined to perform vehicle detection in our experiment. Suppose we have an image I, consisting of many objects/vehicles to be detected. All objects have their different intensities and their separate boundaries and each object is the part of original image I. So, mathematically Q (vehicle) is the subset of image I, and there are number of intensity values inside Q (p, q $\in$ Q). ∂Q is the adjacent region (at least one pixel) of Q but not the part of Q. Q $\subset$ I is extremal region i.e. for all p $\in$ Q and q $\in$ ∂Q : I (p) > I (q) (highest intensity region) and for all p $\in$ Q and q $\in$ ∂Q : I (p) < I (q) (lowest intensity region) and these intensity regions has been evaluated by thresholding. This illustration is for one object in the test image and there is sequence of Qi objects such as Q1, Q2, …., Qi and local minima condition has applied for stability. As For simplicity, this condition in MSER can be explained by the functionality of thresholding. In thresholding, if the pixel value would be under the given threshold then pixel will belong to dark region and if the pixel value would be upper the given threshold then pixel will belong to bright region. Connected components of regions are the set of extremal regions. According to this basic rule we have extracted the desired regions for detection purpose. MSERs work on the intensity values so it does not dependent on the scaling, rotation, twisting and warping. But it is dependent on effects of light which occurs by transform of day to night and vice versa. The stepwise working of proposed method has been described in Fig. 1. The sequence of objects has been extracted by MSER approach and bounding box method was exploited on extracted regions of objects.

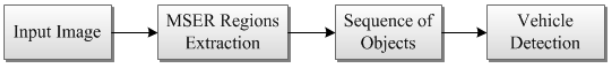

Fig. 1 Flow diagram of proposed method

3. Results and Discussions

MSER is region based optimal algorithm for detection, recognition and classification and it is exploited for vehicle detection in satellite imagery in this proposed framework. The consideration of optical imagery is beneficial for vehicle detection due to optimal performance of MSER for bright regions. The MSER approach has been utilized on several images to detect vehicles and fine-tuning of parameters has been required for each test image separately to get the high accuracy of detection. The proposed MSER approach is not utilizing the training of multiple positive and negative images therefore it is not appropriate for large test set although it will perform optimally without tuning of parameters for similar test images. The detection speed of MSER is effectively high as compared to recent neural network based approaches. The test image has been shown in Fig. 2 which was converted to gray-scale image to extract the MSERs as shown in Fig. 3 and vehicle detection results has been shown in Fig. 4. The number of extracted regions by MSER was 97 at default region area and later extracted regions were reduced to 62 by reducing the range of region area. The black color vehicle has poor visual as compared to others but MSER approach works on the basis of regions therefore MSER has efficiently extracted the black color vehicle region as shown in Figure 3. The test image

has been taken from Google Earth, San Francisco city and experiments have been conducted on INVIDIA GTX 1070 with 8 GB RAM.

Fig. 2 The selected test image for vehicle detection

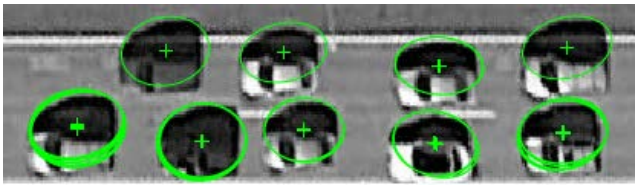

Fig. 3 The extracted MSERs from test image for vehicle detection

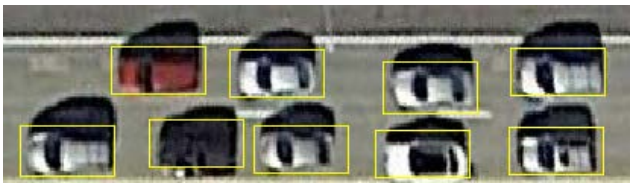

Fig. 4 The vehicle detection result from extracted MSERs

4. Conclusion

Vehicle detection has been examined by using MSERs. We observed that the variation of detection rate is associated with the choice of test image. Although satellite imagery has low resolution and difficult to process but MSERs has provided better accuracy of vehicle detection. This has proved that intensity regions based detection has good impact on satellite images and can be used for remote sensing applications (monitoring, surveillance and control).

For further study we will examine MSERs for object detection in complex environments (occlusions, under shadow regions and under different lighting conditions). Constraints will also be considered for removal of unwanted objects and improvement of detection as well. The preprocessing of images will also improve the detection accuracy in complex environment.

References

[1] Cao L, Luo F, Chen L, Sheng Y, Wang H, Wang C, Ji R. Weakly supervised vehicle detection in satellite images via multi-instance discriminative learning. Pattern Recognition. 2017 Apr 1;64:417-24.

[2] Deng Z, Sun H, Zhou S, Zhao J, Zou H. Toward fast and accurate vehicle detection in aerial images using coupled region-based convolutional neural networks. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing. 2017 Aug;10(8):3652-64

[3] Savastürk D, Froehlich B, Schneider N, Enzweiler M, Franke U. A comparison study on vehicle detection in far infrared and regular images. InIntelligent Transportation Systems (ITSC), 2015 IEEE 18th International Conference on 2015 Sep 15 (pp. 1595-1600). IEEE.

[4] Jiang Q, Cao L, Cheng M, Wang C, Li J. Deep neural networks-based vehicle detection in satellite images. InBioelectronics and Bioinformatics (ISBB), 2015 International Symposium on 2015 Oct 14 (pp. 184-187). IEEE.

[5] Karim S, Zhang Y, Ali S, Asif MR. An improvement of vehicle detection under shadow regions in satellite imagery. InNinth International Conference on Graphic and Image Processing (ICGIP 2017) 2018 Apr 10 (Vol. 10615, p. 106154D). International Society for Optics and Photonics.

[6] F. Fraundorfer and H. Bischof. A novel performance evaluation method of local detectors on non-planar scenes. In Workshop Proceedings of Conference on Computer Vision and Pattern Recognition, 2005.

[7] Stepan Obdrzalek and Jiri Matas, Sub-linear Indexing for Large Scale Object Recognition.

[8] K. Mikolajczyk and C. Schmid. A performance evaluation of local descriptors. IEEE Transactions on Pattern Analysis and Machine Intelligence, pages 1615–1630, October 2005.

[9] Michal Perd'och, 2011 Maximally Stable Extremal Regions and Local Geometry for Visual Correspondences.

[10] J. Matas, O. Chum, M. Urban, and T. Pajdla. Robust wide baseline stereo from maximally stable extremal regions. In Proc. of British Machine Vision Conference, pages 384–396, 2002.

[11] Karim S, Zhang Y, Asif MR, Ali S. Comparative analysis of feature extraction methods in satellite imagery. Journal of Applied Remote Sensing. 2017 Dec;11(4):042618.

[12] Obdržálek D, Basovník S, Mach L, Mikulík A. Detecting scene elements using maximally stable colour regions. InInternational Conference on Research and Education in Robotics 2009 May 21 (pp. 107-115). Springer, Berlin, Heidelberg.

Shahid Karim received his BS degree in Electronics from Comsats Institute of Information Technology, Abbottabad, Pakistan, and MS degree in Electronics and Information Engineering from Xi'an Jiaotong University, China, in 2010 and 2015. He is currently pursuing his PhD at the Department of Information and Communication Engineering, School of Electronics and Information Engineering, Harbin Institute of Technology (HIT), China. His current research interests include image processing, object detection, and classification toward optical remote sensing imagery.

Dr. Imtiaz Ali Halepoto received Bachelor of Engineering degree in Computer Systems Engineering from QUEST Nawabshah, Pakistan, and both M.Sc and PhD from the Department of Computer Science, the University of Hong Kong in 2010 and 2015. Currently, he is working as Assistant Professor at the Department of Computer Systems Engineering QUEST Nawabshah. His research interests are in communication, network protocols, image processing and the optimization of heterogeneous networks.

Dr. Adnan Manzoor received his bachelor's and master's degree in Computer Science from University of Sindh Jamshoro Pakistan in 2001. He received his Master's in Information Technology from QUEST, Pakistan in 2012. He successfully completed hi PhD in Artificial Intelligence from Vrije University Amsterdam Netherlands in 2017. His research interests include, but are not limited to, computational modeling of cognitive and affective processes and study the role of these processes in the context of a person's social network both for purposes of monitoring and support, for example, via mobile phone apps.

Dr. Nazar Hussain Phulpoto is working as Associate Professor at the Department of Information Technology, QUEST Nawabshah. He has PhD degree in Management Sciences and 15 years of research and teaching experience. His research expertise includes Management Sciences and Information Technology.

Asif Ali Laghari received the B.S. degree in Information Technology from the Quaid-e-Awam University of Engineering Science and Technology Nawabshah, Pakistan, in 2007 and Master degree in Information Technology from the QUEST Nawabshah Pakistan in 2014. From 2007 to 2008, he was a Lecturer in the Computer and Information Science Department, Digital Institute of Information Technology, Pakistan. In 2015, he joined the school of the Computer Science & Technology, Harbin Institute of Technology, where he is now a PhD student. He has published more than 10 technical articles in scientific journals and conference proceedings. His current research interests include Computer networks, cloud computing, and multimedia QoE management.