Motion Analysis for Moving Object Detection from UAV Aerial Images:A Review

[1]A.F.M. Saifuddin Saif, [2]Anton Satria Prabuwono
[3]Zainal Rasyid Mahayuddin,
[1, 2, 3] Faculty of Information Science and Technology
University Kebangsaan Malaysia,
43600 UKM Bangi, Selangor D.E., Malaysia
[1] rashedcse25@yahoo.com
[3] zainalr@ftsm.ukm.my

[2]Faculty of Computing and Information Technology
King Abdulaziz University
P.O. Box 344, Rabigh 21911, Saudi Arabia
[2]antonsatria@eu4m.eu

Abstract— **Motion analysis for moving object from UAV aerial images is still an unsolved issue in computer vision research field due to fast abrupt motion of object and UAV, low resolution, noisy imagery, cluttered background, low contrast and small target size. The main reason for the inability to handle motion is the weakness of existing approaches for moving object detection. This paper presents critical analysis of the various methods used for motion analysis which states lack of relevancy with motion analysis along with some unsolved problems need to be solved for optimum performance of moving objects detection from UAV aerial images. The overall reviews proposed in this paper have been extensively studied in various research papers which can significantly contribute to computer vision research and can be potential for future development and direction for future research.**

Keywords—Motion; Moving object; Computer vision

I. Introduction

Motion analysis is the process that constructs a description of image by determination and measurement of image differences in terms of the two dimensional vector field initiated by the displacement and change of shape of the objects in the scene. Motion analysis from aerial images especially for moving has been analyzed in the previous literature from several perspectives i.e. Huang and Tsai [1] presents motion analysis in terms of three approaches, the Fourier method, Marching and differentials while Nagel [2] reviews extensive literature under the applications point of view rather than methodology. Most recently Aggarwal and Nandhakumar [3] present review of motion analysis based on regaining 3-D structure shape of objects. This paper presents review based on the classification of existing recent literatures according to their methodology in a slightly different way to that of Huang and Tsai [1]. The aim of the proposed critical review is to facilitate the future development of adaptive motion model which can influence the overall detection performance.

Proper estimation of motion needs to be initialized which can be a remedy of facing multifactor influence overall detection performance in computer vision research field. Researchers divided current challenges into six categories which are referred as Uncertainty Constraint Factors in terms of detecting moving object from UAV aerial images [59]. Six categories are environment i.e. rural or clutter, object type i.e. 2D or 3D, illumination i.e. fixed or non-fixed brightness, camera i.e. static or moving camera, complexity i.e. low or high complexity. Images with relative environment is an important factor for detecting moving object. Shuqun (2005) considered only clutter environment while in [24][29], the authors considered dynamic background, in [15][23][25], the authors considered both clutter and rural environment along with dynamic and static environment. Due to lack of ability of classifying different objects in the same scene their proposed method did not give a good result in the real time scene.

Some researchers in [14][22][24][28] worked only on even brightness changes which were unrealistic as real time scene cannot be always even while in [15][20][23][29],researchers worked on uneven illumination changes to detect object. Due to constraint of combining even and uneven illumination or brightness changes, their method unrealistic. Finally [8][16] proposed their methods for moving object detection with the combination of both even and uneven condition. Due to inability to detect multiple objects in the same scene, their proposed method did not work well. Regarding object type, [22] used static object for their proposed method. While in [14], the authors used man maid object while they rejected most of the object background image for input aerial images which was unrealistic. Their proposed method for the airborne images results in a high recognition rate only for fixed vibration and fixed illumination changes. Previous research in [16][20][28][29] used static threshold selection for their proposed method which could not give reliable result. Overall work on the specific detection of vehicles or human, encompassing both static and dynamic objects within UAV image gallery is limited. To handle noise free images is one of the main challenges while static camera is appropriate for detecting moving object with fixed or unfixed illumination changes. Previous research in [8][16] used static camera for respective object detection , their proposed method gave good result for rural environment object, not for clutter environment. Besides research in [15][20] used moving camera attached with moving platform while in [22][24],the authors used static camera and moving camera together. Their approach worked well for pure plane approximation, but did not work well for uneven plane.

As moving object detection is involved with moving UAV attached with camera, so detection of motion for both moving object and moving camera along with UAV is the key issue for optimum performance of moving object detection. For this reason, this paper considers motion analysis can be the most effective factor which can affect other factors also for performance measurement. Proper motion parameters estimation for both moving object and camera motion along with UAV vehicle motion can be a good bridge to solve other issues. This paper presents review of existing methods stating the relevancy of motion analysis which can extends the research field of computer vision for moving object detection from UAV aerial images in terms of discovering appropriate methods for motion analysis.

II. RESEARCH METHODOLOGY

For accurate detection, motion must be accurately detected using suitable methods which are affected by a number of practical problems such as motion change over time, unfixed direction of moving object.Object motion along with camera motion contains panning, tilting, rotation, airborne platform and different heights results in different sizes of target objects [1].Through the modelling of motion, detection task becomes easy and thus also can handle noise. All these issues initiate the improvement existing feature extraction techniques as aerial images need to be captured from various altitude levels.

A. Various Features:

This research identified the following features based on the previous research for moving object detection shown in figure 1.

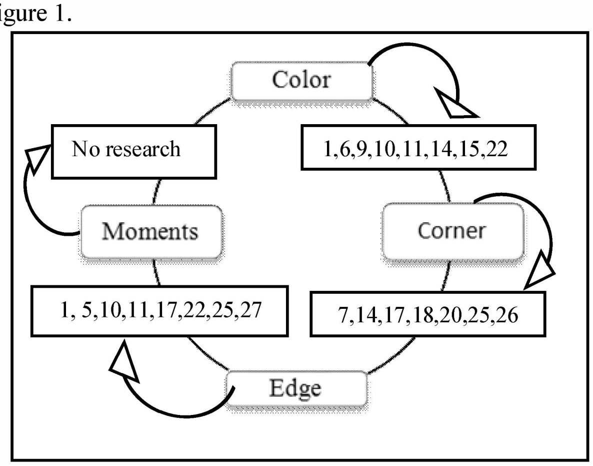

Figure 1. Features used for analysis on previous research.

Previous research in [1], [6], [9], [10], [11], [14], [15], [22] worked on color to detect moving object from UAV aerial images. Due to inability to detect same color moving object separately their research did not give the expected results. Research in [7], [14], [17], [18], [20], [25], [26] used corner features where most of scenarios depend on lightening condition. Finally research in [1], [5], [10], [11], [17], [22], [25], [27] used edge features for moving object detection. Most of their approach engaged to concentrate only on detection rate not in reducing complexity.

Indeed, detection of motion and detection of object are coupled. If proper motion detection is done, detection of moving object from UAV aerial image becomes easier. Very few research concentrates on adaptive robust handling of noise and unfixed motion change as well as unfixed moving object direction. For that reason an adaptive and dynamic motion analysis framework is needed for better detection of moving object from UAV aerial images where overall motion analysis reduces dependency on parameter. In other words, detection of motion indicates detection of motion pixels from frames which can be described as some function of the image pixel intensity. Pixel intensity is nothing but the pixel color value. Moments are described with respect to their power as in raised-to-the-power in Mathematics. Very few previous researches used image moments to presents motion analysis as indicated in figure 1. Thus this paper proposes to use image moments before segmenting individual objects and use motion pattern in turn to facilitate the detection in each frame.

B. Methods

To establish motion model is difficult for most of the time due to some real time multi-factors [21] [42] [59]. Considering of dithering and influencing factor, a fixed threshold value is a crucial factor to make sure the compensation which is valuable to latter object detection [27] [38] [39] [43].Previous research had been done to overcome these multi factors using different approaches, i.e. Lagrangian particle dynamics approach is used to segment high density crowd flows and further track each marked objects [24]. Clustering based approach is proposed to segment and represent the dense motion flow in crowded scenes [24] [38] [69]. These two methods apply pre-filtering or free clustering steps. As the scene may contain different motion patterns at one location within a period of time i.e. road intersection , averaging or filtering before knowing the local structure of motion patterns may destroy such structure. In Figure 2, four existing approaches for motion analysis are shown which have been proposed to improve motion detection on frame-by-frame and pixel by pixel basis. i.e. (a) Global illumination compensation approach works on brightness or illumination changes. Due to depend on brightness, in real world this research does not progress so far. (b) In parallax filtering approach, a scene that contains strong parallax is still difficult for existing methods to achieve good segmentation results [24].(c) In contextual information approach, contextual information has been applied to improve detection of moving object from UAV aerial images [24, 33].This method assumes low level motion detection. The errors in low level motion segmentation under strong parallax situation are not considered in this method. (d) For long term motion pattern analysis [24] approach , there is scope to use context information to improve both low level motion segmentation and high level reacquisition even when there is only one single object in the scene [24].

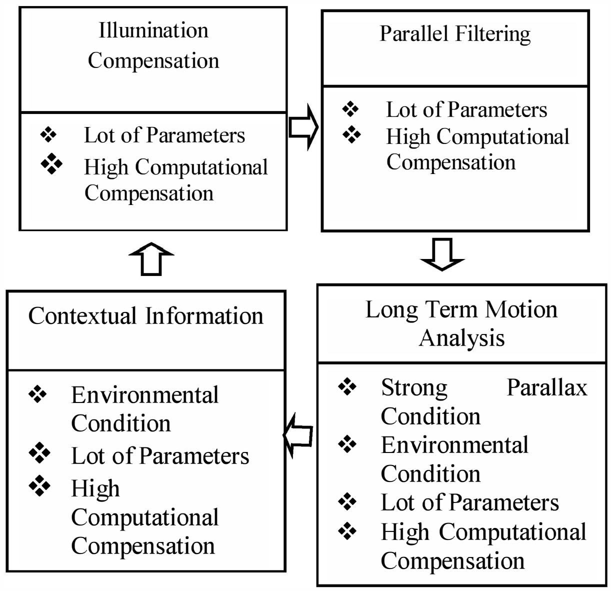

Figure 2. Existing approaches for motion based object detection.

Figure 3 shows the comparison table for compatibility of different approach for motion based moving object detection research from UAV aerial images. In Table I, low level motion indicates motion without parallax; high level motion indicates motion with parallax. Among these 4-types, first three are not distinctive property for moving object because of environmental condition for the first types, a lot of parameter calculation for the second and third type increases computation complexity. Long term motion pattern analysis for moving object detection from UAV aerial images can be used where not much attention has been paid before. The most common problem of motion based moving object detection is the dependency on lot of parameters which increase computational complexity. None of the existing literature concentrates on decreasing parameter dependency which can be a future hot research for motion based moving object detection from UAV aerial images. Thus this paper proposes to analyze motion pattern over a long time period before segmenting individual objects and use motion pattern in turn to facilitate the detection in each frame which will initiates the development of adaptive motion analysis framework for better detection of moving object from UAV aerial images to reduce dependency on parameter.

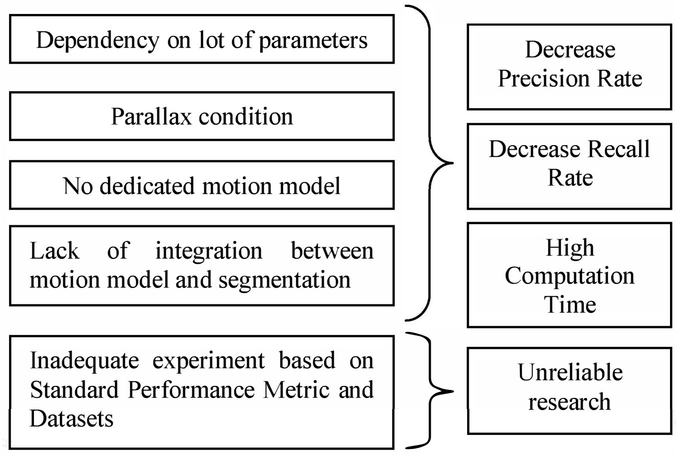

Figure 3. Comparison of parameters for various motion analysis approaches.

III. EXPERIMENT

This paper states performance measurements into two categories for overall object detection from UAV aerial images to ensure reliability of the research i.e. A. Mathematical Performance Metric (MPM), B. Robust Performance Metric (RPM). MPM contains mathematical parameters, i.e. true positive, false positive, false negative, precision rate, detection rate or recall rate, false alarm rate etc. True Positive or TP means detected regions that correspond to a moving object. False Positive or FP means detected regions that do not correspond to a moving object. If moving object cannot be detected then the performance metric named as False Negative or FN. Precision is the ratio between the number of correct matches and the number of testing query images defined as PR, while false alarm rate is the ratio between false positive and true positive matches defined as FAR. Finally detection rate is defined as DR indicates the ratio of true positive with the combination of true positive and false negative shown in figure 4.

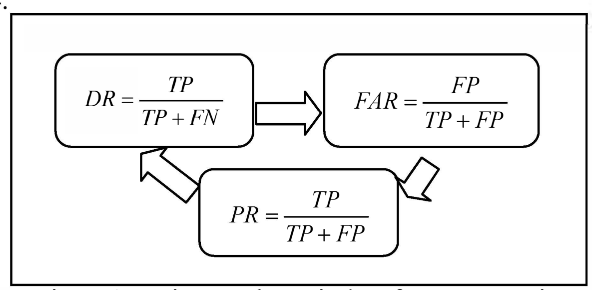

Figure 4. Various mathematical performance metrics.

RPM is used to measure accuracy of moving object detection from UAV aerial image in different environmental condition shown in Figure 5. Environment complexity based experimentation indicates experiment in rural or clutter area within varying rural or industrial settings [15][26].Detection of multiple objects in same scene or in different scene involves detection of same or different object in different environmental situation [26][31][47][51][57][59][63][65][67].

Detection on different size of objects indicates evaluating detection performance based on different dimensional images especially for low resolution UAV aerial images [1] [17][21][25][29][38][43][49].

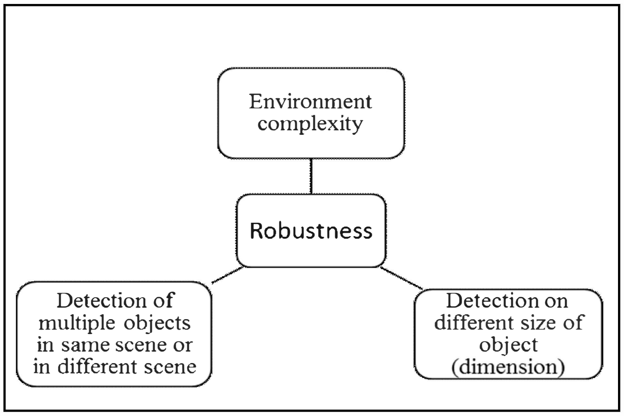

Figure 5. Performance metrics for robustness measurement.

IV. CONCLUSION

The primary purpose of this research is to review all the existing approaches of motion analysis of moving object detection from UAV aerial images in order to gain optimum detection performance. From the critical review demonstrated by this paper , it can be stated that existing motion analysis based moving object detection from UAV aerial images depends on lot of parameters which effects loss of detection performance and increase computational complexity. Meanwhile, existing feature extraction techniques are not appropriate most of the times as aerial images are needed to be captured from different altitudes. This opposite relationship makes the detection task more difficult. For ensuring reliability and robustness to demonstrate motion based moving object detection research, this paper presents Mathematical Performance Metric (MPM) and Robustness Performance Metric (RPM).Judging from the previous research in computer vision field, it is certain that new motion analysis approach needs to facilitate to ensure robust handling of motion as translation invariant, scale invariant and rotationally invariant.

ACKNOWLEDGMENT

This research is supported by Ministry of Higher Education Malaysia research grant scheme of FRGS/1/2012/SG05/UKM/02/12and ERGS/1/2012/STG07/UKM/02/7.

REFERENCES

[1] C. Hsu-Yung, W. Chih-Chia, and C. Yi-Ying, "Vehicle Detection in Aerial Surveillance Using Dynamic Bayesian Networks," *Image Processing, IEEE Transactions on,* vol. 21, pp. 2152-2159, 2012.

[2] V. Reilly, B. Solmaz, and M. Shah, "Shadow casting out of plane (SCOOP) candidates for human and vehicle detection in aerial imagery," *International Journal of Computer Vision,* vol. 101, pp. 350-366, 2013.

[3] Y. Yingqian, L. Fuqiang, W. Ping, L. Pingting, and L. Xiaofeng, "Vehicle detection methods from an unmanned aerial vehicle platform," in *Vehicular Electronics and Safety (ICVES), 2012 IEEE International Conference on*, 2012, pp. 411-415.

[4] T. Pollard and M. Antone, "Detecting and tracking all moving objects in wide-area aerial video," in *Computer Vision and Pattern Recognition Workshops (CVPRW), 2012 IEEE Computer Society Conference on*, 2012, pp. 15-22.

[5] Z. Zezhong, W. Xiaoting, Z. Guoqing, and J. Ling, "Vehicle detection based on morphology from highway aerial images," in *Geoscience and Remote Sensing Symposium (IGARSS), 2012 IEEE International*, 2012, pp. 5997-6000.

[6] T. Moranduzzo and F. Melgani, "A SIFT-SVM method for detecting cars in UAV images," in *Geoscience and Remote Sensing Symposium (IGARSS), 2012 IEEE International*, 2012, pp. 6868-6871.

[7] S. A. Cheraghi and U. U. Sheikh, "Moving object detection using image registration for a moving camera platform," in *Control System, Computing and Engineering (ICCSCE), 2012 IEEE International Conference on*, 2012, pp. 355-359.

[8] H. Bhaskar, "Integrated human target detection, identification and tracking for surveillance applications," in *Intelligent Systems (IS), 2012 6th IEEE International Conference*, 2012, pp. 467-475.

[9] C. Long, J. Zhiguo, Y. Junli, and M. Yibing, "A coarse-to-fine approach for vehicles detection from aerial images," in *Computer Vision in Remote Sensing (CVRS), 2012 International Conference on*, 2012, pp. 221-225.

[10] L. Pingting, L. Fuqiang, L. Xiaofeng, and Y. Yingqian, "Stationary vehicle detection in aerial surveillance with a UAV," in *Information Science and Digital Content Technology (ICIDT), 2012 8th International Conference on*, 2012, pp. 567-570.

[11] A. Kembhavi, D. Harwood, and L. S. Davis, "Vehicle Detection Using Partial Least Squares," *Pattern Analysis and Machine Intelligence, IEEE Transactions on,* vol. 33, pp. 1250-1265, 2011.

[12] J. Maier and K. Ambrosch, "Distortion Compensation for Movement Detection Based on Dense Optical Flow," in *Advances in Visual Computing.* vol. 6938, G. Bebis, R. Boyle, B. Parvin, D. Koracin, S. Wang, K. Kyungnam, B. Benes, K. Moreland, C. Borst, S. DiVerdi, C. Yi-Jen, and J. Ming, Eds., ed: Springer Berlin Heidelberg, 2011, pp. 168-179.

[13] M. Tarhan and E. Altuğ, "A catadioptric and pan-tilt-zoom camera pair objects tracking system for UAVs," *Journal of Intelligent and Robotic Systems: Theory and Applications,* vol. 61, pp. 119-134, 2011.

[14] J. Gleason, A. V. Nefian, X. Bouyssounousse, T. Fong, and G. Bebis, "Vehicle detection from aerial imagery," 2011, pp. 2065-2070.

[15] A. Gąszczak, T. P. Breckon, and J. Han, "Real-time people and vehicle detection from UAV imagery," 2011.

[16] M. Besita Augustin, S. Juliet, and S. Palanikumar, "Motion and feature based person tracking in surveillance videos," in *Emerging Trends in Electrical and Computer Technology (ICETECT), 2011 International Conference on*, 2011, pp. 605-609.

[17] W. Sheng, "Vehicle Detection on Aerial Images by Extracting Corner Features for Rotational Invariant Shape Matching," in *Computer and Information Technology (CIT), 2011 IEEE 11th International Conference on*, 2011, pp. 171-175.

[18] X. Wang, C. Liu, G. Liu, L. Liu, and S. Gong, "Pedestrian Recognition Based on Saliency Detection and Kalman Filter Algorithm in Aerial Video," in *Computational Intelligence and Security (CIS), 2011 Seventh International Conference on*, 2011, pp. 1188-1192.

[19] G. R. Rodríguez-Canosa, S. Thomas, J. del Cerro, A. Barrientos, and B. MacDonald, "A real-time method to detect and track moving objects (DATMO) from unmanned aerial vehicles (UAVs) using a single camera," *Remote Sensing,* vol. 4, pp. 1090-1111, 2012.

[20] C.-H. Huang, Y.-T. Wu, J.-H. Kao, M.-Y. Shih, and C.-C. Chou, "A Hybrid Moving Object Detection Method for Aerial Images," in *Advances in Multimedia Information Processing - PCM 2010*. vol. 6297, G. Qiu, K. Lam, H. Kiya, X.-Y. Xue, C. C. J. Kuo, and M. Lew, Eds., ed: Springer Berlin Heidelberg, 2010, pp. 357-368.

[21] A. W. N. Ibrahim, C. Pang Wee, G. L. G. Seet, W. S. M. Lau, and W. Czajewski, "Moving Objects Detection and Tracking Framework for UAV-based Surveillance," in *Image and Video Technology (PSIVT), 2010 Fourth Pacific-Rim Symposium on*, 2010, pp. 456-461.

[22] O. Oreifej, R. Mehran, and M. Shah, "Human identity recognition in aerial images," 2010, pp. 709-716.

[23] W. Changxia, C. Xianbin, L. Renjun, and W. Fei, "Registration-based moving vehicle detection for low-altitude urban traffic surveillance," in *Intelligent Control and Automation (WCICA), 2010 8th World Congress on*, 2010, pp. 373-378.

[24] Q. Yu and G. Medioni, "Motion pattern interpretation and detection for tracking moving vehicles in airborne video," 2009, pp. 2671-2678.

[25] K. Bhuvaneswari and H. Abdul Rauf, "Edgelet based human detection and tracking by combined segmentation and soft decision," in *Control, Automation, Communication and Energy Conservation, 2009. INCACEC 2009. 2009 International Conference on*, 2009, pp. 1-6.

[26] T. P. a. B. Breckon, S.E. and Eichner, M.L. and Wahren, K., "Autonomous Real-time Vehicle Detection from a Medium-Level UAV," in *24th International Conference on Unmanned Air Vehicle Systems*, 2009.

[27] Z. Jiang, W. Ding, and H. Li, "Aerial video image object detection and tracing based on motion vector compensation and statistic analysis," in *Microelectronics & Electronics, 2009. PrimeAsia 2009. Asia Pacific Conference on Postgraduate Research in*, 2009, pp. 302-305.

[28] Y. C. Chung and Z. He, "Low-complexity and reliable moving objects detection and tracking for aerial video surveillance with small UAVs," 2007, pp. 2670-2673.

[29] D. Wei, G. Zhenbang, X. Shaorong, and Z. Hairong, "Real-time vision-based object tracking from a moving platform in the air," 2006, pp. 681-685.

[30] Z. Shuqun, "Object Tracking in Unmanned Aerial Vehicle (UAV) Videos Using a Combined Approach," in *Acoustics, Speech, and Signal Processing, 2005. Proceedings. (ICASSP '05). IEEE International Conference on*, 2005, pp. 681-684.

[31] T. Pollard and M. Antone, "Detecting and tracking all moving objects in wide-area aerial video," in *Computer Vision and Pattern Recognition Workshops (CVPRW), 2012 IEEE Computer Society Conference on*, 2012, pp. 15-22.

[32] M. Teutsch and W. Kruger, "Spatio-temporal fusion of object segmentation approaches for moving distant targets," in *Information Fusion (FUSION), 2012 15th International Conference on*, 2012, pp. 1988-1995.

[33] C. Guilmart, S. Herbin, and P. Perez, "Context-driven moving object detection in aerial scenes with user input," in *Image Processing (ICIP), 2011 18th IEEE International Conference on*, 2011, pp. 1781-1784.

[34] M. Teutsch and W. Kruger, "Detection, Segmentation, and Tracking of Moving Objects in UAV Videos," in *Advanced Video and Signal-Based Surveillance (AVSS), 2012 IEEE Ninth International Conference on*, 2012, pp. 313-318.

[35] I. H. Mtir, K. Kaaniche, M. Chtourou, and P. Vasseur, "Aerial sequence registration for vehicle detection," in *Systems, Signals and Devices (SSD), 2012 9th International Multi-Conference on*, 2012, pp. 1-6.

[36] R. B. Rodrigues, S. Pellegrino, and H. Pistori, "Combining Color and Haar Wavelet Responses for Aerial Image Classification," in *Artificial Intelligence and Soft Computing*. vol. 7267, L. Rutkowski, M. Korytkowski, R. Scherer, R. Tadeusiewicz, L. Zadeh, and J. Zurada, Eds., ed: Springer Berlin Heidelberg, 2012, pp. 583-591.

[37] S. G. Fowers, D. J. Lee, D. A. Ventura, and J. K. Archibald, "The nature-inspired BASIS feature descriptor for UAV imagery and its hardware implementation," *IEEE Transactions on Circuits and Systems for Video Technology,* vol. 23, pp. 756-768, 2013.

[38] J. Lu, P. Fang, and Y. Tian, "An Objects Detection Framework in UAV Videos," in *Advances in Computer Science and Education Applications*. vol. 202, M. Zhou and H. Tan, Eds., ed: Springer Berlin Heidelberg, 2011, pp. 113-119.

[39] A. Camargo, Q. He, and K. Palaniappan, "Performance evaluation of optimization methods for super-resolution mosaicking on UAS surveillance videos," 2012.

[40] M. Teutsch, W. Krüger, and N. Heinze, "Detection and classification of moving objects from UAVs with optical sensors," 2011.

[41] L. L. Coulter, D. A. Stow, Y. H. Tsai, C. M. Chavis, C. D. Lippitt, G. W. Fraley, and R. W. McCreight, "Automated detection of people and vehicles in natural environments using high temporal resolution airborne remote sensing," 2012, pp. 78-90.

[42] L. Wang, H. Zhao, S. Guo, Y. Mai, and S. Liu, "The adaptive compensation algorithm for small UAV image stabilization," 2012, pp. 4391-4394.

[43] M. Bhaskaranand and J. D. Gibson, "Low-complexity video encoding for UAV reconnaissance and surveillance," 2011, pp. 1633-1638.

[44] X. Tan, X. Yu, J. Liu, and W. Huang, "Object tracking based on unmanned aerial vehicle video," *CCIS,* vol. 224 pp. 432-438, 2011.

[45] Z. Lin, C. Ren, N. Yao, and F. Xie, "A shadow compensation method for aerial image," *Wuhan Daxue Xuebao (Xinxi Kexue Ban)/Geomatics and Information Science of Wuhan University,* vol. 38, pp. 431-435, 2013.

[46] K. Imamura, N. Kubo, and H. Hashimoto, "Automatic moving object extraction using x-means clustering," in *Picture Coding Symposium (PCS), 2010*, 2010, pp. 246-249.

[47] S. Mohamed and K. Takaya, "Motion vector search for 2.5D modeling of moving objects in a video scene," in *Electrical and Computer Engineering, 2005. Canadian Conference on*, 2005, pp. 265-268. Test

[48] L. Renjie, Y. Songyu, and Y. Xiaokang, "Efficient Spatio-temporal Segmentation for Extracting Moving Objects in Video Sequences," *Consumer Electronics, IEEE Transactions on,* vol. 53, pp. 1161-1167, 2007.

[49] Z. Yihua, L. Yongli, and Z. Jianbiao, "A video semantic object extraction method based on motion feature and visual attention," in *Intelligent Computing and Intelligent Systems (ICIS), 2010 IEEE International Conference on*, 2010, pp. 845-849.

[50] T. Dutta, D. P. Dogra, and B. Jana, "Object Extraction Using Novel Region Merging and Multidimensional Features," in *Image and Video Technology (PSIVT), 2010 Fourth Pacific-Rim Symposium on*, 2010, pp. 356-361.

[51] P. Jinhui, L. Shipeng, and Z. Ya-Qin, "Automatic extraction of moving objects using multiple features and multiple frames," in *Circuits and Systems, 2000. Proceedings. ISCAS 2000 Geneva. The 2000 IEEE International Symposium on*, 2000, pp. 36-39 vol.1.

[52] S. Ning and Q. Xu, "A comparison of features extraction method for HMM-based motion recognition," in *Environmental Science and Information Application Technology (ESIAT), 2010 International Conference on*, 2010, pp. 636-639.

[53] Z. Shoujuan and Z. Quan, "New feature extraction algorithm for satellite image non-linear small objects," in *Electrical & Electronics Engineering (EEESYM), 2012 IEEE Symposium on*, 2012, pp. 626-629.

[54] X. F. Wu, X. S. Wang, and H. Z. Lu, "Motion feature extraction for stepped frequency radar based on Hough transform," *Radar, Sonar & Navigation, IET,* vol. 4, pp. 17-27, 2010.

[55] H. Kaiqi, Z. Yeying, and T. Tieniu, "A Discriminative Model of Motion and Cross Ratio for View-Invariant Action Recognition," *Image Processing, IEEE Transactions on,* vol. 21, pp. 2187-2197, 2012.

[56] P. C. Hytla, K. S. Jackovitz, E. J. Balster, J. R. Vasquez, and M. L. Talbert, "Detection and tracking performance with compressed wide area motion imagery," in *Aerospace and Electronics Conference (NAECON), 2012 IEEE National*, 2012, pp. 163-170.

[57] A. F. M. S. Saif, A. Prabuwono, and Z. Mahayuddin, "Real Time Vision Based Object Detection from UAV Aerial Images: A Conceptual Framework," in *Intelligent Robotics Systems: Inspiring the NEXT.* vol. 376, K. Omar, M. Nordin, P. Vadakkepat, A. Prabuwono, S. Abdullah, J. Baltes, S. Amin, W. Hassan, and M. Nasrudin, Eds., ed: Springer Berlin Heidelberg, 2013, pp. 265-274.

[58] A. F. M. S. Saif, A. Prabuwono, and Z. Mahayuddin, "Adaptive Motion Pattern Analysis for Machine Vision Based Moving Detection from UAV Aerial Images," in *Advances in Visual Informatics.* vol. 8237, H. Zaman, P. Robinson, P. Olivier, T. Shih, and S. Velastin, Eds., ed: Springer International Publishing, 2013, pp. 104-114.

[59] A. F. M. S. Saif, A. Prabuwono, and Z. Mahayuddin, "A Review of Machine Vision based on Moving Objects: Object Detection from UAV Aerial Images", IJACT,2013 Vol. 5, No. 15, pp. 57 ~ 72.

[60] A. F. M. S. Saif, A. Prabuwono, and Z. Mahayuddin, "Adaptive Long Term Motion Pattern Analysis for Moving Object Detection Using UAV Aerial Images", *International Journal of Information System and Engineering (IJISE2013),2013 Vol* 1(1),pp.50-59.

[61] Trihaminto, H. H., Prabuwono, A. S., Saiffuddin Saif, A. F. M. & Adji, T. B. , "A Conceptual framework: Dynamic path planning system for simultaneous localization and mapping multirotor UAV", 2014, *Advanced Science Letters* 20(1),pp.299-303.

[62] C. Shyi-Chyi, "Visual pattern matching in motion estimation for object-based very low bit-rate coding using moment-preserving edge detection," *Multimedia, IEEE Transactions on,* vol. 7, pp. 189-200, 2005.

[63] J. Liang, T. F. Xu, M. Z. Shi, L. Feng, K. Zhang, G. Q. Ni, and X. Y. Wang, "A method to improve accuracy of parameter identification for single image blurred by uniform linear motion," *Beijing Ligong Daxue Xuebao/Transaction of Beijing Institute of Technology,* vol. 32, pp. 818-823, 2012.

[64] C. L. Zhong, Y. L. Ding, and J. B. Fu, "Forward image motion compensation for aerial camera based on neural network predictive control," *Binggong Xuebao/Acta Armamentarii,* vol. 33, pp. 706-711, 2012.

[65] S. C. Cheng, W. K. Huang, and T. L. Wu, "A fast global motion estimation for moving objects segmentation using moment-preserving technique," 2005, pp. 3455-3458.

[66] X. Cao, C. Gao, J. Lan, Y. Yuan, and P. Yan, "Ego motion guided particle filter for vehicle tracking in airborne videos," *Neurocomputing,* vol. 124, pp. 168-177, 2014.

[67] H. Kalinić, S. Lončarić, and B. Bijnens, "Absolute joint moments: A novel image similarity measure," *Eurasip Journal on Image and Video Processing,* vol. 2013, 2013.

[68] M. Sayyouri, A. Hmimid, and H. Qjidaa, "Improving the performance of image classification by Hahn moment invariants," *Journal of the Optical Society of America A: Optics and Image Science, and Vision,* vol. 30, pp. 2381-2394, 2013.

[69] R. Ozawa and F. Chaumette, "Dynamic visual servoing with image moments for an unmanned aerial vehicle using a virtual spring approach," *Advanced Robotics,* vol. 27, pp. 683-696, 2013.

[70] G. Jia, X. Wang, H. Wei, and Z. Zhang, "Modeling image motion in airborne three-line-array (TLA) push-broom cameras," *Photogrammetric Engineering and Remote Sensing,* vol. 79, pp. 67-78, 2013.

[71] J. Guo, D. Gu, S. Li, and H. Chang, "Moving object detection using motion enhancement and color distribution comparison," *Beijing Hangkong Hangtian Daxue Xuebao/Journal of Beijing University of Aeronautics and Astronautics,* vol. 38, pp. 263-267+272, 2012.