A Review on Image Processing Techniques for Fisheries Application

E A Awalludin¹, T N T Arsad¹ and W N J Hj Wan Yussof²

¹Faculty of Fisheries and Food Science, Universiti Malaysia Terengganu (UMT), 21030 Kuala Nerus, Terengganu, Malaysia
²Faculty of Ocean Engineering Technology and Informatics, Universiti Malaysia Terengganu (UMT), 21030, Kuala Nerus, Terengganu, Malaysia.
e.afreen@umt.edu.my

Abstract. Nowadays, the image processing technique has been used widely in the fields of science and technology. The use of the image processing technique is to improve the manual approach process to achieve accurate results. Since the manual approach shows, its time processing can be laborious to analyses extensive data and require a skilful researcher to experiment. The use of image processing technique can support to reduce several drawbacks. Therefore, many researchers prefer an alternative solution such as an automated or semi-automated system-based image to enhance the manual approach task. The image processing technology provides a variety of algorithms that modified according to the desired study is the reason why the image processing technique is desirable. Low-level processing is the early stage of image processing techniques and the steps involved are image acquisition, noise removal, image sharpening, image smoothing, image blurring, etc. Meanwhile for the Mid-level processing, adopt the use of several image processing techniques such as image segmentation, object detection, object recognition, feature extraction and classification. Therefore, image processing provides numerous applications such as in agriculture, medical image processing, ocean monitoring and conservation, facial recognition, fisheries, etc. In this paper, the uses of image processing techniques are discussed in briefly on the application of fishery study.

1. Introduction

The A digital image is derived from an analog image in a 2D continuous space and described in a 2D discrete space after undergoes digitization. Each sample of the image is called pixel and used to represent all the elements in a digital image. Digital image composed of a finite number of elements called picture elements, image elements, and pixels that have a particular location and value. Well-defined as two-dimensional function \( f(x, y) \), an image is known as a digital image when the value of \( x, y \), and amplitude of have limited distinct numbers [1].

The digital image processing technique is one of the essential techniques to enhance raw images received from various sources such as cameras or satellites’ sensor, space probes, aircraft, etc. Image processing technique could assist in the quality enhancement of the original image and prepared the image for machine interpretation. Image processing techniques deal with input images, pre-processing, image segmentation, feature extraction and image classification, etc., [2].
Morphology operations applied to the input image to process image based on the structure to produce the same structure of output image [3]. Morphological operation divided into dilation [4], erosion [5], opening [6] and closing [7]. Digital image processing contributes to the filtering of noise, reconstruction of image and compression of image [8]. Distortion in an image caused by scattering of light, attenuation of light, blurring of an image, etc. Scattering and absorption phenomena influence the dispersion of light and the quality of obtained images [9]. Blurring on an image occurred when there is motion between the camera and captured the object during photographing, and the information spills into neighbouring pixels [10].

Noise is visible as grains in the image when the pixels in the image show different intensity values instead of actual pixel values. During the process of image acquisition, transmission and storage noise impulse repeatedly spoiled produced images [11]. Impulse noise (Salt-and-pepper noise), Amplifier noise (Gaussian noise), Shot noise, Quantization noise (uniform noise), Film grain, on-isotropic noise, Multiplicative noise (Speckle noise) and Periodic noise are the type of noise that can exist in an image [12]. The filtering process includes smoothing (low-pass filter), sharpening (high-pass filter) and edge enhancement. Various types of noises in the images filtered by a filter such as median filter [13], mean filter [14], Gaussian filter [15], Laplacian filter [16], Laplacian of Gaussian filter [17] etc. Feature extraction and segmentation of images helps in reducing the amount of data for analysis. Example of feature extraction techniques are spatial features [18], transform features [19], edge and boundary features [20], colour features, shape features and texture features. Classification of image could be performed by using blob processing [21], support vector machine (SVM) [22], neural network [23], K-nearest neighbour (K-NN) [24].

In general, Image processing widely used by the researcher in a variety of fields that include medicine, agriculture, industry and law enforcement. Digital Image Processing (DIP) commonly applied in the recognition process, remote sensing, image enhancement, color and video processing, medical field, etc., [25]. Rao [26] also mention that the uses of image processing are for visualization, image sharpening, restoration, image recognition, etc.

2. The use of image processing techniques in fisheries application
In the fisheries study, the number of research publication that using computer technology based on image processing techniques is still very limited. The use of computer technology in their work routines is still decreasing as they still believe in the manual methods approach. However, there are several drawbacks that can affect the work processes when using the manual approach method such as time consuming, sequential process, requiring high knowledge, over-estimation, human intervention, etc. Therefore, in this paper we would like to share the idea and knowledge from previous studies of some authors that use fusion of image processing techniques in fisheries application as shown in Table 1.

| Fields               | Authors       | Methods                                                                 | Findings                                                                 |
|---------------------|---------------|-------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Fish classification | Hu et al. [27]| Using color model space of (RGB and HSV), Color feature extraction, and applying the classifier of multi-class support vector machine (MGSVM). | DAGMSVM technique is chosen as an effective technique even though 0.19% less accurate than VBMSVM, but DAGMSVM recorded the lowest average time to categorize the fish into their species. |
|                     | Rathi et al. [28] | Using a combination classifier of Convolutional Neural Network (CNN) and | The result of the proposed method shows a 96.29% accuracy rate |

Table 1. Relevant studies of image processing techniques in fisheries application
| Reference          | Method Description                                                                                                                                   | Result                                                                 |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| Li and Hong [29]   | Combination of several image processing techniques such as image enhancement and segmentation. Selection of fish species data amount using principal component analysis (PCA) and SPSS. | The process of classification achieves 96.67% accuracy rate for fish species classification. |
| Rachmatullah and Supriana [30] | Proposed the use of fusion of image processing techniques that consists of image enhancement, segmentation and feature extraction. For classifier the Convolutional Neural Network (CNN) was used to classify low resolution of fish images. | The output result shows that the proposed method achieves 99.7% successful accuracy rate and outperforms compared to other methods. |
| Alsmadi et al. [31] | To recognize fish object by extracting texture feature (gray level co-occurrence matrix (GLCM) of fish images, anchor points, and statistical measurements. Implemented the use of Memetic Algorithm (Genetic Algorithm with Simulated Annealing) and combined with the back-propagation algorithm (MA-B Classifier). | Based on the outputs results, the proposed method achieves 82.25% and 90% accuracy recognition rate through 400 fish images dataset where 250 of fish images was used for training dataset and 150 of fish images for testing dataset. |
| Fish classification/counting and abundance | Proposed a novel balance-enforced optimized tree with reject option (BEOTR) to recognise live fish from the open sea. In the study their trajectory voting is used to eliminate accumulated errors, Gaussian mixture model and Bayes rule to evaluate the posterior probability. | The technique used is useful for ecologists for the long term and continuous monitoring activities by providing automatic recognition software. |
| Le and Xu [33]     | Conducted a study using an automated system, improved algorithm of Otsu method to count the stock of fish in an aquarium.                               | The findings showed that compared to the previous technique, the new technique produces less than 6% of the average counting error. |
| Authors          | Methodology                                                                 | Results/Findings                                                                 |
|------------------|------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Marini et al. [34] | K-fold Cross-Validation Procedure.                                            | Average accuracy of average accuracy of 92% with a standard deviation (std) equal to 0.02, a true positive rate (TPR) equals 95% with std equals to 0.03 and a false positive rate (FPR) that equals 12% with std equals 0.04. |
| Lumauag and Nava [35] | Proposed the use of image processing techniques to count and track fish population from the image. The fish images was analyzed using blob analysis and Euclidean distance filtering. | The output results show that the proposed method is outperformed which high accuracy achieved successfully as well as detecting fish from the image. |
| Zheng and Zhang [36] | Use digital picture and classifier of fuzzy artificial neural networks (ANNs).  | 95% of accuracy was achieved where ANNs effectively count overlapped fish.       |
| Kaewchote et al. [37] | Using texture feature of Local Binary Pattern (LBP) and color features of Red, Green, Blue (RGB) and the Random Forest (RF) classifier to classify shrimp larvae. | 98.50% of accuracy shown by LBP method and 14.43 mean square error recorded due to the overlapping shrimp. |
| Spampinato et al. [38] | Using an automated Video Processing (VP) system, texture feature and color analysis to count fish. | Average success rate was 85% through number of 20 underwater videos dataset. The proposed method is outperforms compared to existing counting methods. |
| Aliyu et al. [39] | Proposed the use of several image processing techniques such as image acquisition, image pre-processing, image segmentation, feature extraction, classification to count fingerling. | Proposed method was expected to produce high accuracy results compared to existing method to count different sizes of fingerling. |
| Raman et al. [40] | Proposed the framework using machine learning techniques with aims to reduce cost and provide efficient method for fish study and growth. Among | The output results shows that the proposed framework achieved successful accuracy 82.5% for larvae and 87.5% for juvenile. |
| **Fish weight and length measurement** | **Islamadin et al. [41]** | Using an automatic visual capture to estimate length, width, weight and height of the fish. Image processing techniques involved in the study consist of segmentation, feature extraction and statistical analysis. | Based on their finding results, the classification performance achieved accuracy results from range 80% to 97%. |
| **Al-Jubouri et al. [42]** | Proposed a new models to estimate length of small-size free-swimming fish objects using low-cost machine vision system. In their study two camera are used and setup with orthogonal and stereo to capture fish image. The distance and length are recorded to measure the actual length of the object. | The output results show that the length measurement achieved the lowest percentage error rate within the range of ± 1%. |
| **Fish Detection/Tracking/ Identification** | **Allken et al. [43]** | Utilised a deep learning neural network (NN) to identify fish species that present in the images from the Deep Vision trawl camera system. | Based on the experimental results, the proposed method achieved 94% accuracy results through number of 15000 images (5000 per species) dataset. |
| **Li and Hong [44]** | Using combination of image processing techniques to detect four fish species. Among the process of image processing techniques involve such as image enhancement, image segmentation, edge detection, feature extraction and classification task. | Results show that average recognition rate for identifying fish species category is 96.67%. |
| **Dutta et al. [45]** | Proposed an image processing method automatically, efficient and non-destructive. There are two objectives of this study which to segment fish tissues and to determine fish | The technique was quick, high accuracy, remarkable and non-destructive to test the freshness of the fish, but varied based on different characteristics |

Image processing techniques used such as Image Acquisition, Image Enhancement, Segmentation and Classification, to detect young larvae and juvenile fish.
| Topic                                   | Reference          | Methodology                                                                 | Result                                                                 |
|----------------------------------------|--------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------|
| Freshness through the fish sample      | Boudhane and Nsiri [46] | Combination of image denoising by Poisson-Gauss mixture algorithm, image segmentation via mean-shift algorithm, and the other is Log-Likelihood ratio test for robust fish detection. | Proposed technique could adapt with various noise models such as additive colored noise and non-Gaussian noise, by modifying the algorithm. |
| Fish disease                           | Malik et al. [47]   | The proposed method is developed using combination of image processing techniques to identify Epizootic Ulcerative Syndrome (EUS) from fish body. Among image processing techniques used such as Segmentation, morphological operation, edge detection, features extraction and classifier. | Based on the experimental results, the proposed method based on the combination of FAST-PCA-NN achieved 86% accuracy rate where it is the highest accuracy compared to existing methods. |
| Fish tissue                            | Sengar et al. [48]  | Proposed the use of image processing techniques to extract skin tissue of fish in order to identify fish freshness. The HSV color model is used to identify degradation pattern for fish freshness. | The Output Results shows that 96.66% accuracy was achieved using a combination of image processing methods. |
| Arora et al. [49]                      |                    | Using image processing techniques based on the Wavelet Transform to extract the properties of fish gill tissues. | From the technique used degradation of fish freshness can be determined more efficiently and fast. Based on the output results, various patterns of fish gill tissues can be obtained from the statistical wavelet feature. |
| Coral reef study and fish abundance    | Kaeli, et al. [50]  | Proposed the use of morphological operator and texture features extraction to segment out areas of coral reef cover in the image. | The percentage of coral cover in deeper-reef zones was determined successfully compared to some established method. |
| Awalludin et al. [51]                  |                    | Using different types of edge detection techniques (Robert operator, Prewitt operator, Sobel operator, LoG operator and Canny edge) | The discovery of the study showed that the Canny edge detector is the best edge detector compared to others edge methods. |
| **Detector** | **Modified Detection** | **Finding** |
|--------------|------------------------|-------------|
| Awalludin et al. [52] | Applying the use of Modification of canny edge detection for coral reef components estimation distribution from underwater video transect. Among image processing techniques such as image enhancement, segmentation, edge detection and blob processing. | In the meantime, combination of image processing techniques and blob processing provide fast time processing to determine the coral reef distribution as compared to the manual technique. |
| Awalludin et al.[53] | Proposed the use of color feature extraction from Hue Saturation Value (HSV) color model and texture feature from Local Binary Pattern (LBP) All the features of color and texture were used into the classifier of Multilayer Perceptron Neural Network (MPLNN) to estimate coral reef distribution. | The findings showed that a combination of color and texture technique produces a 92.60% accuracy rate. Meanwhile, Hue, Saturation Value (HSV) is 81.30% accuracy, and Local Binary Pattern (LBP) descriptor obtains 88.10% accuracy rate. |
| Jokiel et al. [54] | The proposed method is performance based on the several techniques such as quadrat, random, point intercept point (PTT), CRAMP RAT, video transect, towed-diver, photoquad, NOAA ground truth. | From the different techniques applied, quadrat techniques record the highest number of species detected while "NOAA Ground Truth" and "Towed-diver" had the lowest number. |
| Mumby et al. [55] | Applied structure-from-Motion (SfM) to describe the topographic structure of coral reef in a 3-dimensional view. | Rock-rubble state the highest percentage cover as 74.75% at the French Frigate Shoals study site and *P. lobate* has 10.96% of percentage cover make it the dominant species at the same study site. |
| Underwater image enhancement | Peng and Cosman [56] | Implementation of the use of a depth estimation method for underwater scenes based on image blurriness and light absorption, which can be used in the image formation model (IFM) to | In the experimental finding shows that the proposed method resulting in better restoration and enhancement in different color tones and |
3. Conclusions

Digital image processing is the use of the computer algorithm to perform image processing on the digital image. It deals with sharpening, conversion, blurring, detecting edge detection, recognition, etc. The application of digital image processing in fisheries or marine fields technically still under study by researchers. Overall it may be said that the application of image processing in the various field can be one of the alternative solutions to the manual technique where the time processing can be reduced, a fast estimation can be obtained and more reliable. It is very useful in the research area especially in monitoring large study areas and to obtain large sample datasets. The digital image processing technique can provide the researcher with high accuracy result in a short time. Through several modifications, technology is providing much better results in various studies. Development or modification of coral reef monitoring using digital image processing techniques can contribute to the stable number of the fish population through underwater study in the future with better accuracy and less time consumed.

Image processing techniques play a big role in ocean conservation. Therefore, monitoring activity by applying image processing will be able to maintain a healthy ecosystem by lowering the possibilities of extinction of species. A healthy ecosystem can provide us with natural resources (i.e. foods and drugs), services (i.e. recycling and purification of water and air), recreational activities and high species biodiversity. A variety of species creates a larger gene pool and provides high survival options in changing conditions. Each of the species plays an important role genetically and removing it will give a negative impact on the ecosystem. The image processing algorithm must be modified according to a different study conducted to gain the best result.

Acknowledgments

The author is greatly grateful thank you to Ministry of Education (MOE) for the financial support through FRGS VOT No: 59544

References

[1] Gupta G 2011 Algorithm for image processing using improved median filter and comparison of mean, median and improved median filter International Journal of Soft Computing and Engineering (IJSCCE) 1(5) pp 304-311
[2] Gamage P T 2017 Identification of brain tumor using image processing techniques Faculty of Information Technology, University of Moratuwa. https://www.researchgate.net/publication/276133543
[3] Chitradevi1 B, and Srimathi P 2014 An Overview on Image Processing Techniques International Journal of Innovative Research in Computer and Communication Engineering 2(11)
[4] Liu S, Dong L, Liao X, Hao Y, Cao X, and Wang X 2019 A Dilation and Erosion-Based Clustering Approach for Fault Diagnosis of Photovoltaic Arrays IEEE Sensors Journal 19(11) pp 4123-4137
[5] Abbas A H, Kareem A A, and Kamil M Y 2015 Breast cancer image segmentation using morphological operations International Journal of Electronics and Communication Engineering and Technology 6 pp 08-14
[6] Raid A M, Khedr W M, El-Dosuky M A, and Aoud M 2014 Image restoration based on morphological operations International Journal of Computer Science, Engineering and Information Technology (IJCSEIT) 4(3) pp 9-21
[7] Irshad M, Muhammad N, Sharif M, and Yasmeen M 2018 Automatic segmentation of the left ventricle in a cardiac MR short axis image using blind morphological operation The European Physical Journal Plus 133(4) p 148
[8] Pitas I 2000 Digital image processing algorithms and applications John Wiley and Sons
[9] Drews P L, Nascimento E R, Botelho S S, and Campos M F M 2016 Underwater depth estimation and image restoration based on single images IEEE computer graphics and applications 36(2) pp 24-35
[10] Jassim H A, Hussain Z M, Shaaban H R, and Al-dbag K B 2015 Blurring and deblurring digital images using the dihedral group International Journal of Advanced Research in Artificial Intelligence (IJARAI) 4(12)
[11] Chan R H, Ho C W, and Nikolova M 2005 Salt-and-pepper noise removal by median-type noise detectors and detail-preserving regularization. IEEE Transactions on image processing 14(10) pp 1479-1485
[12] Verma R and Ali J 2013 A comparative study of various types of image noise and efficient noise removal techniques. International Journal of advanced research in computer science and software engineering 3(10)
[13] Erkan U, Gökrem L, and Enginoğlu S 2018 Different applied median filter in salt and pepper noise Computers and Electrical Engineering 70 pp 789-798
[14] Hiary H, Zaghloul R, Al-Adwan A, and Moh’d B A Z 2017 Image contrast enhancement using geometric mean filter Signal, Image and Video Processing 11(5) pp 833-840
[15] Issac J, Wüthrich M, Cifuentes C G, Bohg J, Trimpe S, and Schaal S 2016, Depth-based object tracking using a robust gaussian filter International Conference on Robotics and Automation (ICRA) pp 608-615
[16] Hao S, Wang M, Hong R, and Jiang J 2016 Spatially guided local Laplacian filter for nature image detail enhancement Multimedia Tools and Applications 75(3) pp 1529-1542
[17] Mohamad A S, Halim N S A, Nordin M N, Hamzah R, and Sathar J 2018 Automated Detection of Human RBC in Diagnosing Sickle Cell Anemia with Laplacian of Gaussian Filter Conference on Systems, Process and Control (ICSPC) pp 214-217
[18] Bellegarda J R, Dolfing J G, and Naik D K 2015 Integrating feature extraction via local sequential embedding for automatic handwriting recognition U.S. Patent No. 8,977,059 Washington DC U.S. Patent and Trademark Office
[19] Acharya U R, Fujita H, Sudarshan V K, Mookiah M R K, Koh J E, Tan J H, and Ng K H 2016 An integrated index for identification of fatty liver disease using radon transform and discrete cosine transform features in ultrasound images Information Fusion 31(C) pp 43-53
[20] Sowmya V, Mohan N, and Soman K P 2015 Edge detection using sparse banded filter matrices Procedia Computer Science 58 pp 10-17
[21] Yusuf M D, Kusumarto R D, Oktarina Y, Dewi T, and Risma P 2018 BLOB Analysis for Fruit Recognition and Detection. Computer Engineering and Applications Journal 7(1) pp 23-32
[22] Huppertz H J, Möller L, Südmeyer M, Hilker R, Hattingen E, Egger K, and Pinkhardt E H 2016 Differentiation of neurodegenerative parkinsonian syndromes by volumetric magnetic resonance imaging analysis and support vector machine classification Movement Disorders 31(10) pp 1506-1517
[23] Lin Z, Ma D, Meng J, and Chen L 2018 Relative ordering learning in spiking neural network for pattern recognition Neurocomputing 275 pp 94-106
[24] Chen C H, Huang W T, Tan T H, Chang C C, and Chang Y J 2015 Using k-nearest neighbour classification to diagnose abnormal lung sounds Sensors 15(6) pp 13132-13158
[25] Chitradevi B, and Srimathi P 2014 An Overview on Image Processing Techniques International Journal of Innovative Research in Computer and Communication Engineering 2(11)
[26] Rao R M, and Arora M K 2004 Overview of image processing In Advanced image processing techniques for remotely sensed hyperspectral data Springer, Berlin, Heidelberg pp 51-85
[27] Hu J, Li D, Duan Q, Han Y, Chen G, and Si X 2012 Fish species classification by color, texture and multi-class support vector machine using computer vision Computers and electronics in agriculture 88 pp 133-140
[28] Rathi D, Jain S, and Indu S 2017 Underwater fish species classification using convolutional neural network and deep learning Ninth International Conference on Advances in Pattern Recognition (ICAPR) pp 1-6

[29] Li L, and Hong J 2014 Identification of fish species based on image processing and statistical analysis research International Conference on Mechatronics and Automation pp 1155-1160.

[30] Rachmatullah M N, and Supriana I 2018 Low Resolution Image Fish Classification Using Convolutional Neural Network 5th International Conference on Advanced Informatics: Concept Theory and Applications (ICAICTA) pp 78-83

[31] Alsmadi M.K, Omar K.B, and Noah S A 2011 Fish Classification Based on Robust Features Extraction From Color Signature Using Back-Propagation Classifier Journal of Computer Science 7(1) pp 52-58

[32] Boom B J, He J, Palazzo S, Huang P X, Beyan C, Chou H M, and Fisher R B 2014 A research tool for long-term and continuous analysis of fish assemblage in coral-reefs using underwater camera footage Ecological Informatics 23 pp 83-97

[33] Le J, and Xu L 2017 An Automated Fish Counting Algorithm in Aquaculture Based on Image Processing International Forum on Mechanical, Control and Automation (IFMCA 2016) Atlantis Press

[34] Marini S, Fanelli E, Sbragaglia V, Azzurro E, Fernandez J D R, and Aguzzi J 2018 Tracking fish abundance by underwater image recognition Scientific reports 8(1) p 1374

[35] Lumauag R G and Nava M 2018 Fish Tracking and Counting using Image Processing 10th International Conference on Humanoid, Nanotechnology, Information Technology Communication and Control, Environment and Management (HNICEM) pp 1-4

[36] Zheng X, and Zhang Y 2010 A fish population counting method using fuzzy artificial neural network International Conference on Progress in Informatics and Computing volume 1 pp 225-228

[37] Kaewchote J, Janyong S, and Limprasert W 2018 Image recognition method using Local Binary Pattern and the Random forest classifier to count post larvae shrimp Agriculture and Natural Resources 52(4) pp 371-376.

[38] Spampinato C, Chen-Burger Y H, Nadarajan G and Fisher R B 2008 Detecting, Tracking and Counting Fish in Low Quality Unconstrained Underwater Videos VISAPP (2) pp 514-519

[39] Aliyu I, Gana K J, Musa A A, Agajo J, Orire A M, Abiodun F T and Adegboye M A 2017 A proposed fish counting algorithm using digital image processing technique Journal of Science, Technology and Education 5(1) pp 1-11

[40] Raman V, Perumal S, Navarathnam S, and Fazilah S 2016 Computer Assisted Counter System for Larvae and Juvenile Fish in Malaysian Fishing Hatcheries by Machine Learning Approach JCP 11(5) pp 423-431

[41] Islamadina R, Pramita N, Arnia F, and Munadi K 2018 Estimating fish weight based on visual captured. International Conference on Information and Communications Technology (ICOIACT) pp 366-372

[42] Al-Jubouri Q, Al-Nuaimy W, Al-Tace M A and Young I 2017 Towards automated length-estimation of free-swimming fish using machine vision 14th International Multi-Conference on Systems, Signals & Devices (SSD) pp 469-474

[43] Allken V, Handegard N O, Rosen S, Schreyeck T, Mahiout T, Malde K, and Handling editor: Richard O’Driscoll 2018 Fish species identification using a convolutional neural network trained on synthetic data ICES Journal of Marine Science 76(1) pp 342-349

[44] Li L, and Hong J 2014 Identification of fish species based on image processing and statistical analysis research. In 2014 IEEE International Conference on Mechatronics and Automation pp 1155-1160

[45] Dutta M K, Issac A, Minhas N, and Sarkar B 2016 Image processing-based technique to assess fish quality and freshness Journal of Food Engineering 177 pp 50-58
[46] Boudhane, M., and Nsiri, B 2016 Underwater image processing method for fish localization and detection in submarine environment Journal of Visual Communication and Image Representation 39 pp 226-238.

[47] Malik S, Kumar T, and Sahoo A K 2017 Image processing techniques for identification of fish disease IEEE 2nd International Conference on Signal and Image Processing (ICSIP) pp 55-59

[48] Sengar N, Gupta V, Dutta M K and Travieso C M 2018 Image Processing Based Method For Identification Of Fish Freshness Using Skin Tissue 4th International Conference on Computational Intelligence and Communication Technology (CICT) pp 1-4.

[49] Arora M, Mangipudi P, Dutta, M K and Burget R 2018 Image Processing Based Automatic Identification of Freshness in Fish Gill Tissues International Conference on Advances in Computing, Communication Control and Networking (ICACCCN) pp 1011-1015

[50] Kraeli J W, Singh H, and Armstrong R A 2006 An automated morphological image processing based techniqueology for quantifying coral cover in deeper-reef zones In OCEANS pp 1-6

[51] Awalludin E A, Hitam M S, Bachok Z, Yussof W N J, and Muslim A M 2013 Anisotropic diffusion based edge detector for detecting coral reefs edges International Conference on Signal and Image Processing Applications pp 226-231

[52] Awalludin E A, Hitam M S, Yussof W N J H W, and Bachok Z 2017 Modification of canny edge detection for coral reef components estimation distribution from underwater video transect International Conference on Signal and Image Processing Applications (ICSIPA) pp 413-418

[53] Awalludin E A, Hitam M S, Yussof W N J H W, and Bachok Z 2017 Classification of Coral Reef Components Using Color and Texture Features Journal of Telecommunication, Electronic and Computer Engineering (JTEC) 9(3-4) pp 109-113

[54] Jokiel P L, Rodgers K S, Brown E K, Kenyon J C, Aeby G, Smith W R, and Farrell F 2015 Comparison of techniques used to estimate coral cover in the Hawaiian Islands PeerJ 3 954

[55] Mumby P J, Skirving W, Strong A E, Hardy J T, LeDrew E F, Hochberg E J, and David L T 2004 Remote sensing of coral reefs and their physical environment Marine pollution bulletin 48(3-4) pp 219-228

[56] Peng Y T, and Cosman P C 2017 Underwater image restoration based on image blurriness and light absorption IEEE transactions on image processing 26(4) pp 1579-1594