**CHAPTER 2**

**Review of Related Literature**

**2.1 Future Perspective of real time plankton-imaging-system**

One research studies the future perspective of automating the image analysis of plankton in which the researchers said that the major requirement to achieve any progress in addressing biological diversity in ocean plankton is the high-resolution sensors for imaging field-collected and *in situ* specimens in a non-invasive manner (Culverhouse,2006). They further explained that a large distributed Database in the form of high-resolution 3D rotatable plankton images must be created to attain automatic categorization of species.

The research proposes several advancements in plankton-imaging-system. First, to establish a standard of taxonomic quality images of specimens that will be validated for use in automatic categorisation machines and for other scientific researches. Second, to identify ‘holes’ in taxonomic expertise in basic technology developers. Hence, through validation of the database contents, experts for the taxonomy of specific groups would become more ‘visible’ and approachable to the wider community. Lastly, to disseminate images of unknown species to experts across the world, through the World Wide Web. This would provide the widest possible access to expert taxonomic opinions (Culverhouse,2006).

All of the stated proposed advancements were made entirely for all plankton species in the ocean but not particularly for copepods.

**2.2 ZOOSCAN digital imaging systems**

ZOOSCAN is a system for identifying and counting plankton net samples. It describes image processing and semi-automatic recognition using various machine learning methods of plankton species.

The system showed an accuracy level 85% in classifying taxa of plankton species and a faster than manual sample handling thanks to the new combined algorithm known as discriminant vector forest (Grosjean,2004).

Although the system showed promising results, copepods were not entirely studied in this research.

**2.3 Diffraction patterns as a tool for recognition**

Diffraction patters were used for 3 species of Calanoid copepods. The images were digitized, binarized and edited to remove debris present and to simulate different degrees of segmentation. A total of 28 segmented images of the three species were generated to get their digital fourier transform of diffraction pattern. The method has a lot of potential but it needs more research to develop an automatic system for plankton identification (Zavala-Hamz,1996).

**2.4 Circular Harmonic Filters**

CHF’s are group of filters which most widely used method of accomplishing rotation invariance. The filters have several advantages. First, the correlation plane is invariant to rotation, and second, they are proven sensitive to noise. The main disadvantage of the use of CHF’s is that they lose their power of discrimination if the expansion center, is not previously selected (Zavala-Hamz,1997).

Researchers found out that the symmetry of genus Acartia permitted discrimination to the species and sex levels, while the asymmetry of the genus Calanus permitted discrimination only to the generic level. The differences among organisms of different sex of the genus Calanus could not be detected by these particular CHF’s.

The researchers suggested that more research should be carried out to implement an automated optodigital system to identify and count marine plankton.

**2.5 Novel Study in Copepod Automatic copepod identification and Classification**

Another study about the Identification and Classification of copepods by L.K. Leow et.al in 2015 uses Image processing and neural network. The researchers used Matlab’s image processing software. They used eight species of copepods namely *Acartia spinicauda, Bestiolina similis, Oithona aruensis, Oithona dissimilis, Oithona simplex, Parvocalanus crassirostris, Tortanus barbatus and Tortanus forcipatus*. The researcher used 240 samples which were then divided into three sets, the training set (168 samples, or 70% of samples), validation set (36 samples, 15%) and testing set (36 samples, 15%). The data from the training set were used for network training; the validation set for measuring network generalization and terminating training before overfitting; and the testing set for independent measure of network performance during and after training. The overall approach demonstrated not only a fast and automated technique for copepod identification and classification but also an accuracy rate of 93.13%. The performance evaluation of the system was evaluated using MSE or the Mean Square Error and Confusion matrices. The other 160 independent samples (20 samples from each species) were used for system performance evaluation. The trained network was simulated using the testing data as input and the output was then compared to the predicted data and recorded in a confusion matrix.

His approach demonstrated an overall classification accuracy of 93.13% (100% for A. spinicauda, B. similis and O. aruensis, 95% for T. barbatus, 90% for O. dissimilis and P. crassirostris, 85% for O. similis and T. forcipatus).

Although his work showed a promising result, it still needs improvements especially in feature extraction method used and the selected features used.

**2.6 Artificial Neural Networks**

There are many types of neural networks such as Hopfiled Neural Network,Radial Basis Function Neural Network, Probabilistic Neural Network, Convolution Neural Network,Fuzzy Neural Network but one of the most famous used for image segmentation is the Feed Forward Neural Network (Z. Shi and L. He, 2010). Shi and He also noted in their study (“Application of Neural Networks in Medical Image Processing”) that the said network is less sensitive to the selection of the training sets than the Maximum Likelihood classifier.

Neural networks have been utilized in many fields of science especially in image or samples of species’ detection, recognition and classification. It is used in Insect classification by J. Wang et.al in their study “A new automatic identification system of insect images at the order level”. It was also utilized in other species or groups organisms such as Macroinvertebrates by S. Kiranyaz et.al in their study “Classification and retrieval on macroinvertebrate image databases using evolutionary RBF neural networks”; Algae by P. Coltelli et.al in their study “Water monitoring: automated and real time identification and classification of algae using digital microscopy” in 2014; Fishes in the study “Fish recognition based on robust features extraction from size and shape measurements using

neural network” by MK Alsmadi et.al in 2010 and other groups of organisms such as protozoa and metazoa (Y.P. Ginoris et.al, 2007), dinaflagellates (PF Culverhouse et.al, 1996), etc. However only Leow and his colleagues have use neural network for copepod classification.

In Leow’s study, A two-layer (hidden and output layer) feed-forward network was trained using a back-propagation algorithm which is based on ten neurons at the hidden later and eight neurons at the output layer. They used a total of 240 sample images for training set with 30 for each class. They obtained seven selected features of each species which is used as input data presented to the input nodes of the network from the training set, whereas eight desired output classes were defined by the target data. The results showed 93% correct classification from the confusion matrix of all 240 samples in the training, validation, and testing sets.