Underwater Imaging Using Underwater Vehicle for Subsea Surveillance

by

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CERTIFICATION OF APPROVAL

Application Of Collagen As A Filter Aid In Water Treatment Process

by

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A project dissertation submitted to the

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in partial fulfilment of the requirement for the

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(ELECTRICAL AND ELECTRONICS)

Approved by,

____

(Dr. Syed Saad Azhar Ali)

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TRONOH, PERAK

April 2015

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

LIM SHENG SOON

ABSTRACT

This Final Year Project (FYP) focuses on the improvement of images captured through the built-in underwater camera in the HydroView MAX, which is a Remotely-operated Vehicle (ROV) used to perform inspections in subsea environment. Images captured underwater are always degraded due to issues such as light scattering and colour changes. Image-processing algorithms are applied to improve the degraded images so that the images obtained will be enhanced and closer to their true colours for further analysis. These qualities are required so that the degree of corrosion of the underwater pipelines can be estimated with considerable reliability. The estimation of the corrosion degree is made possible by judging on the percentage of corroded surface over the pipeline surface based on the binary image generated.

ACKNOWLEDGEMENT

Firstly, I would like to express my utmost gratitude to my supervisor for this project, Dr. Syed Saad Azhar Ali for his guidance and support provided throughout the planning and execution phase of this project. Without his aid, this project would not have been completed within the time frame allocated.

Next, I would like to thank the Head of Electrical and Electronics Engineering Department for allocating the budget for this project to purchase the underwater vehicle (HydroView MAX).

Last but not least, I would like to thank my family and friends for providing me with unwavering support while I was facing troubles in the project. Their support and suggestions have helped me to triumph over all the challenges faced along the way.

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CHAPTER 1 INTRODUCTION

1.1 Background of Study

Ranked as the second largest oil and gas producer in the region, Malaysian oil companies such as SHELL, ExxonMobil and Petronas Carigali had long been active industrial players in the oil and gas exploration field. Naturally, there are extensive subsea pipeline network in both deepwater and shallow water. Despite all the efforts in corrosion prevention, the condition of the pipelines will still corrode gradually. In order to perform underwater pipeline corrosion inspection or life assessment, there are mainly two ways to get this task done. The conventional way is the deployment of commercial divers. This method is very costly and risky at the same time. On the other hand, underwater vehicles are used to capture stills or even videos of the subsea environment. In either way, images obtained serve the purpose of classifying the underwater pipelines based on their respective conditions. However, a problem lies where the images captured are far from ideal for the analysis processes. The distinctive properties of light in water cause the images captured to be degraded, mainly due to light scattering and colour changes. Therefore, image processing is required to enhance the underwater images for further analysis.

1.2 Problem Statement

- Light scattering and colour changes cause hazy and bluish effects to underwater images. Reduced visibility and contrast of images make estimation of corrosion degree of pipelines more difficult. These images captured during the pipeline corrosion inspection should be enhanced by improving their contrast and making them closer to their true colours so that degree of corrosion of pipelines can be determined with better accuracy.

1.3 Objectives

- To improve degraded images captured in underwater environment.
- To estimate the degree of corrosion of underwater pipelines.

1.4 Scope of Study

- With no prior experience nor knowledge on image processing before undertaking this project, the **basics of image processing** have to be studied in depth so that these theories can be applied as per needed when it comes to the application.
- Various **MATLAB toolboxes** such as Image Acquisition Toolbox, Image Processing Toolbox and so on need to be studied in detail so that suitable ones can be identified as per requirement although there are a variety of toolboxes providing similar functions.

1.5 Relevancy and Feasibility

- This project is highly-relevant because it implies image processing theories which can be acquired online the textbook and engineering solving skills. Besides, this project actually aims to provide a solution to the Oil and Gas industries for underwater pipeline inspection.
- It is feasible within the allowed duration due to the availability of such a wide range of image processing algorithms and MATLAB toolboxes.

CHAPTER 2 LITERATURE REVIEW

In image processing, image segmentation plays one of the most imperative roles because it helps in segregating the intended object from its backdrop, which might act as an interruption when it comes to further image processing or analysis purposes. Especially with the increasingly common use of colour images. There are two major elements in image segmentation, namely choosing a suitable colour space and applying the segmentation algorithms which will provide the intended results, such as threshold histogram and region separation [1].

The simplest yet the most common approach for image segmentation purposes is thresholding[2]. This image processing method works in a way that it separates image pixels into portions and segregating them from the backdrop in the process. These image pixels are categorized into two classes based on their intensity. Basically, if the intensity of an image pixel is higher than the specified threshold, it falls under a category to which those having lower intensity than the threshold will be classified in another category. There are two main categories in this algorithm. The first one is the global thresholding, which is not ideal if there is an uneven illumination in the background while another one is the local thresholding, whereby the uneven lightings can be compensated with multiple threshodings. The downside of thresholding method is that the images pixels are only group into two classes, not ideal for multichannel pictures and unreliable in the presence of noise.

Another available image segmentation method is known as the “Contrast Limited Adaptive Histogram Equalization” (CLAHE) enhancement and Thresholding. In this algorithm, the CLAHE is first used to enhance the quality of image and histogram thresholding is utilized to perform image segmentation, which is linked with pattern recognition [3]. CLAHE is computationally-extensive and used to enhance image offline. The method that is proposed to segment the intended objects and backdrop in subsea surrounding is histogram thresholding. CLAHE separates the captured images into non-overlapping regions of same sizes before applying histogram equalization to them. These regions are categorized into three groups namely corner, border and inner regions [4]. In such a way, the hidden portions of an image can be made clearer because the used grey values has been evened out. By using the CLAHE algorithm, sharp field edges can be retained with selective enhancement in the field borders. This result can be achieved with the processing of only portions of images that falls in the field edge after the field edge has been detected in a portal image. Besides, with the application of CLAHE, filtering of median and sharpening of edges, high spatial frequency can be obtained together with a reduction of noise, which is ideal for further image processing or analysis.

Minimum Description Length (MDL) approximation can also be used as an algorithm for image segmentation because breaks points are automatically generated. Firstly, junction candidates alongside the related regions of interest are generated after these candidates are detected via a pre-processing procedure. They are the compared and matched with borders as per spatial coincidence. Simple matching criterion are already sufficient because the interested regions are extracted from local image structures. Thereafter, a provisional break point will appear at the edge point nearest to the junction. The break point hypotheses is tested for its degree of trueness by using the MDL approximation, which can categorize the edge portions into "straight" or "curved" [5].

After obtaining the intended segments or regions of an image, the images have to be enhanced especially those images captured in an underwater environment because of a few phenomenon especially light scattering. Light scattering takes place because of the presence of particles or haze in water, which reflect and deflect the incident light on an object before finally arriving at the camera, causing the image to be more blurry and lower image contrast. Another reason for the need of image enhancement is the reduction of intensity of light with different wavelengths as it travels underwater, which is the cause of colour changes. Thus, Wavelength Compensation and Image Dehazing (WCID) is proposed to enhance the images by first segmenting the front portion from the backdrop of the image after Dark Channel prior is applied to estimate the distance between the objects and camera [6]. They are then compared if there are any artificial illumination during the image-capturing, judging from their respective light intensities. Then, the haze issues and wavelength attenuation discrepancies are adjusted. Subsequently, based on the residual energy ratios of backdrop light's colour channels, the colour change phenomenon can then be solved when the colour balance is restored according to the attenuation amount of the respective light wavelength. A similar approach while confronting the issue of haze-affected image was correcting the while balance and decomposing the image. An enhanced dark channel prior-based method is deployed to de-haze reflex lightness image while an estimation of exposure adjustment is made from ambience illumination image [7].

Fusion principle is another means of image enhancement in underwater environment. The algorithm proposed only needs a still image rather than multiple pictures [8]. The first of three main parts for the fusion principle is the fusion process input. Here, a combination of a few images is processed and only the most significant characteristics of these input images are retained. From the initially degraded image, two inputs from fusion step are derived. The first being an image with corrected colour while another derived input is a contrast-enhanced image captured in a subsea environment with reduced noise. The second step of the proposed enhancement method is the definition of weight measures. There are four types of weights which are discussed, namely the Laplacian and Local contrast weight, Saliency weight and Exposedness weight. Basically, more weights contribute to better pixels in the eventual image. The last step of the method is the process of Multi-scale Fusion. By applying Laplacian operator to various scales, these inputs are decomposed into a pyramid accordingly, which provides an ideal trade-off between the accuracy of the image captured and the time needed. Another fusion algorithm proposed is wavelet packet transform-based to combine images from multiple sensors. The Discrete Wavelet Packet Transform decomposes and regenerate images. Various frequency ranges are processed in distinguished ways by merging images in wavelet packet space [9].

Apart from that, there is also a feasible underwater image enhancement method which can be achieved with the application of Integrated Colour Model. The main principle behind this algorithm is slide stretching. There are mainly two steps, namely the equalization of images' colour contrast by contrast stretching the RGB algorithm and increment of image true colour by using HSI's saturation and intensity stretching. By manipulating the image colour elements, the HSI model allows a wider range of colour, mainly the S and I. With an increment or decrement of that value, the contrast ratio in subsea images could be controlled. This step is made possible applying a histogram on the images' digital values. The stretching value is then redistributed over a maximum range. By referring to less output values, stronger values can be provided by the linear stretching of Saturation, and thus generating better visual displays. In order to maintain the appropriate colour ratio, each colour channel is stretched to the same scale during the colour stretching algorithm application. This could be done by first obtaining a well-spread histogram. Then, the RGB image is transformed into HSI by using S and I transfer function so that the brightness and the true colour of the images captured underwater can be increased [10].

Then, there is a need to recognize the objects in subsea condition. Synthetic Aperture Sides (SAS) is a method proposed to perform a variety of operations such as seabed mapping and oil exploration [11]. In the pre-processing of sonar images, homomorphic filtering is introduced to solve the problem of illumination non-uniformity based on Fourier transform together with a Gaussian filter which is "H" modified. Meanwhile, wavelet transform is applied to reduce noise acquisition. After that, textural analysis of sonar images are carried out which is actually feature extraction in image processing. The final approach in SAS is segmentation and classification of sonar images using an array of algorithms such as Higher Order Statistics, Support Vector Machine (SVM) Classifier and also the incorporation of fuzzy logic in SVM.

CHAPTER 3 METHODOLOGY

3.1 Research Methodology

The author started out by reading research papers found online which discuss about image processing methods to improve underwater images. Although all those methods proposed by the papers aim to solve similar problems, which is to enhance degraded images, there are a variety of algorithms and approach being used. Therefore, the more the research papers being studied, the more likely the author is able to identify the best algorithms for the image enhancement purpose.

Besides, different types of MATLAB Toolboxes are being studied. There are quite a number of potential Toolboxes which had been identified from the long list of available MATLAB. For instance, the Image Processing Toolbox is used to perform image enhancement, segmentation, analysis and algorithm development. Besides, the author found out that Image Acquisition can be used to acquire stills or even videos from cameras, which are industrial-standard hardware directly into MATLAB. This is a good feature to load the images captured into MATLAB to be processed for further analysis. After some detailed research and attempts, the enhancement of underwater images and corrosion degree estimation based on the proposed methods and algorithms are summarized as the flow chart below.

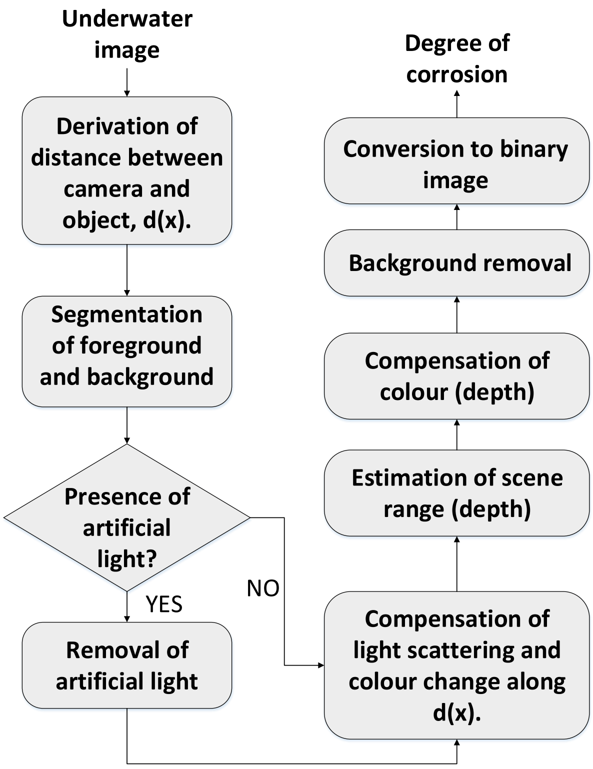

Figure 1. Flow chart of the proposed underwater imaging method

3.2 Project Activities

The author started out by procuring the steel pipes from scrap yards. The more samples (steel pipes) accumulated, the more it would be able to show that the method proposed is reliable in the image improvement and estimation of the steel pipes based on their degree of corrosion. Besides, the author made sure that the samples are of similar lengths and circumferences. This measure is taken to ensure more consistency and reliability in the database.

Since the platform of this project is MATLAB, the author has to strengthen his basics in MATLAB and ask for assistance from some professionals out there regarding the project he is undertaking. Thus, he has participated in the Innovate Malaysia 2015, whereby trainings are provided. In training, a revision for MATLAB and Simulink basics is provided and coaching is given to trigger students to think of more ways to solve their problems in their projects.

After collecting enough of steel pipes as samples, the author started to take pictures of them, which will then be compared against pipes in the underwater images. The surface area which are covered with rust (corroded) will be computed in percentage using MATLAB. Below are images of a few samples with different degree of corrosion.

Figure 2. Samples with different degree of corrosion

As mentioned earlier, these images will be captured using the HydroView MAX. However, underwater image capturing has started earlier using an underwater camera owned by the author, which is SJCAM 5000. This 14-Mega-Pixel camera can be connected easily to laptop for further image processing through a USB cable. Firstly, images were captured on ground (normal, dry atmosphere). Then, underwater images were captured in a blue tank to mimic underwater environment. To enhance the similarity of environment, the tank was filled up with dust (makes the environment hazy, which was actually caused by light scattering). The initial idea to add a few drops of blue dye into the water was not used because the image captured is already bluish enough. The actual bluish environment is caused by colour change in water.

Later on, the underwater vehicle arrived so the author and his friend tested out the vehicle under the company of their supervisor. The underwater vehicle was controlled and monitored using a WIFI modem which came together with the vehicle itself. However, the underwater vehicle malfunctioned even before the author could capture any image with it. The following weeks had been used to repair the HydroView MAX by constantly receiving mails on instructions to troubleshoot the problem from the company who supplied this vehicle to us, which is Aquabotix. After several weeks, the underwater vehicle was up and running again.

3.3 Key Project Milestones

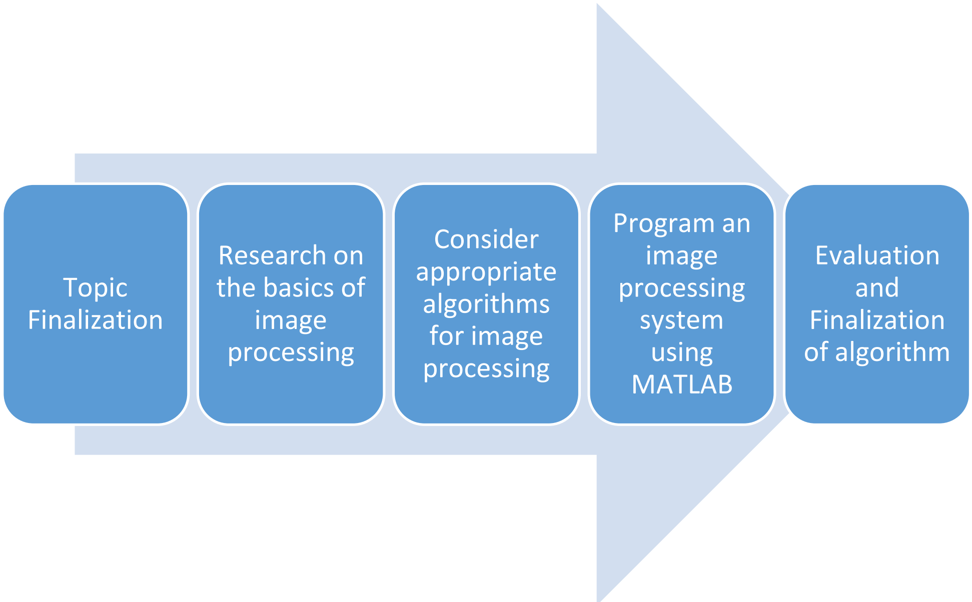

Figure 3. Key Project Milestones

After finalizing the topic, the author proceeded to study on the basics of image processing online because he has no prior experience in this area. After studying quite a number of algorithms from research papers, the author selected one of the methods, which is known as the Wavelength Compensation and Image Dehazing (WCID) to be incorporated into his project, which aimed to improve degraded underwater images and estimate the corrosion degree of sample pipelines.

3.4 Project Timeline (Gantt Chart)

No.	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Title	■	■												
2	Research the Basics of image processing and Hydroview MAX		■	■	■	■									
3	Extended proposal submission						■								
4	Procurement of specimens (pipes) from scrap yard							■	■	■	■	■	■	■	■
5	MATLAB simulation of image segmentation and enhancement								■	■	■	■	■	■	■
6	Proposal defence									■					
7	Innovate Malaysia Competition training (MATLAB platform)										■				
8	Submission of Interim Draft Report													■	
9	Submission of Interim Report														■

Figure 4. Gantt Chart for first phase of project

No.	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Image Processing algorithm development	■	■	■	■	■	■	■	■	■	■				
2	Progress Report submission								■						
3	Poster Design								■	■	■				
4	ELECTREX											■			
5	Draft Final Dissertation													■	
6	Final Dissertation submission														■
7	Techical Paper submission														■
8	Viva														
9	Final Dissertation submission (hard cover)														

Figure 5. Gantt Chart for second phase of project

Innovate Malaysia training for MATLAB platform, which was held on 28 – 30 November 2014 in the Dream Catcher Training Centre at Krystal Point, Penang helped the author to revisit all the basics of MATLAB/SIMULINK, interface of MATLAB with Arduino boards and usage of MATLAB toolboxes.

Even though the procurement of sample pipes from scrap yard would have been completed in the first phase of the project, it has been continued during phase two of the project because the number of samples obtained has been too little to prove that the image processing method is reliable enough. The capturing of images, may it be on land or in underwater environment were not included in either one of the two Gantt charts because this process is repeated throughout phase one and two whenever new sample pipeline has been successfully procured from the scrap yard.

During the ELECTREX, a few doubts and questions from the judges have been taken note of for future improvement and recommendations because the remaining time is already too short to make any significant changes to the project. For the technical report, it will have less than 5 pages in IEEE format. As for the VIVA, it will be held on the study week (20-22 April 2015) and the Final Dissertation with hard cover to be submitted on 18 May 2015.

CHAPTER 4 RESULTS AND DISCUSSION

4.1 Results

At first, the images of one of the sample pipeline are taken on land and in a blue container with clear water. The threshold are all set at almost the same value, which is 0.3 when those images are to be converted to binary images so that the resultant image generated will be uniform and reliable. The corroded portion of the pipeline will appear as black in the binary image generated while the remaining white portion in the binary image represents surface which are still not corroded.

Figure 6. Actual RGB image of a sample on land (1st sample)

Figure 7. Black and white image of the actual RGB image (1st sample)

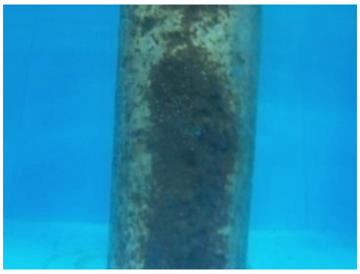

Figure 8. Original underwater RGB image of a sample (1st sample)

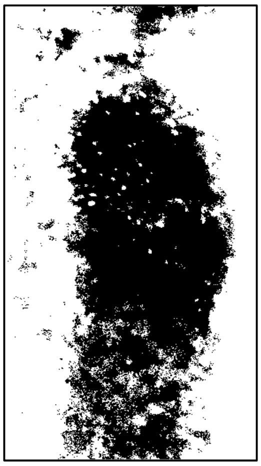

Figure 9. Black and white image of the original underwater RGB image (1st sample)

Figure 10. Improved underwater RGB image of a sample (1st sample)

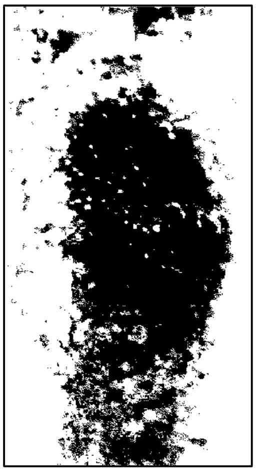

Figure 11. Black and white image of the improved underwater RGB image (1st sample)

Table 1. Degree of corrosion of 1st sample as per MATLAB results

Figure	Location of image captured and image nature	Percentage of corrosion
6	On land and raw	41.3837%
8	Underwater and raw	38.6222%
10	Underwater and processed	39.0488%

The result of sample one in Table 1 shows that there is not much difference on the degree of corrosion of pipelines no matter the image is taken on land or underwater, may it be raw or processed. The reason being the water is still clear (not hazy), thus reducing the effect of light scattering effect. Thereafter, some dust has been added into the water container to mimic the environment of underwater (hazy and bluish).

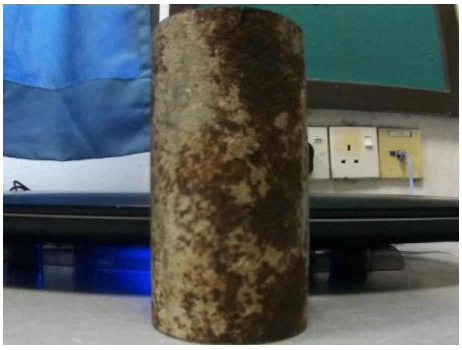

Figure 12. Actual RGB image of a sample on land (2nd sample)

Figure 13. Black and white image of the actual RGB image (2nd sample)

Figure 14. Original underwater RGB image of a sample (2nd sample)

Figure 15. Black and white image of the original underwater RGB image (2nd sample)

Figure 16. Improved underwater RGB image of a sample (2nd sample)

Figure 17. Black and white image of the improved underwater RGB image (2nd sample)

Table 2. Degree of corrosion of 2nd sample as per MATLAB results

Figure	Location of image captured and image nature	Percentage of corrosion
12	On land and raw	57.8419%
14	Underwater and raw	46.3473%
16	Underwater and processed	63.4275%

Based on Table 2, the difference between the estimated corrosion degree of the actual (on land) sample and the corrosion degree of sample pipeline in the raw (unprocessed) underwater image is larger than that of the processed image, which comes to show that the effect of the image processing algorithm is starting to become more significant already. Therefore, the author proceeded to add more dust into the water to make it more turbid or hazy.

Figure 18. Actual RGB image of a sample on land (3rd sample)

Figure 19. Black and white image of the actual RGB image (3rd sample)

Figure 20. Original underwater RGB image of a sample (3rd sample)

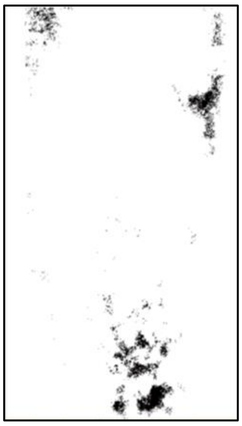

Figure 21. Black and white image of the original underwater RGB image (3rd sample)

Figure 22. Improved underwater RGB image of a sample (3rd sample)

Figure 23. Black and white image of the improved underwater RGB image (3rd sample)

Figure 18, Figure 20 and Figure 22 are of the same sample with the difference of location of image capturing (land and underwater) and the nature of the image, either raw (Figure 18 and 20) or processed (Figure 22).

Table 3. Degree of corrosion of 3rd sample as per MATLAB results

Figure	Location of image captured and image nature	Percentage of corrosion
18	On land and raw	35.9047%
20	Underwater and raw	2.3959%
22	Underwater and processed	31.4398%

Now that the environment where the image is captured is more similar to subsea environment, the difference in corrosion degree between raw and improved (processed) images is quite significant based on Table 3. When the image captured on land is acquired using MATLAB and converted into black and white image, it shows that the degree of corrosion as 35.9047%. There are little or no loss of information in the image because the properties of light on land (colour change and light scattering) are of minimum effect. However, when the same sample is used and placed underwater, it shows that the degree of corrosion has dropped significantly because the underwater images are hazy and bluish, causing a lot of information loss in the image. After that, the image is improved using the proposed algorithm (WCID) and it shows a significant of lost information recovered, thus explaining why the increased degree of corrosion compared to the raw underwater image. To further prove the reliability of this method, more samples are tested.

Figure 24. Actual RGB image of a sample on land (4th sample)

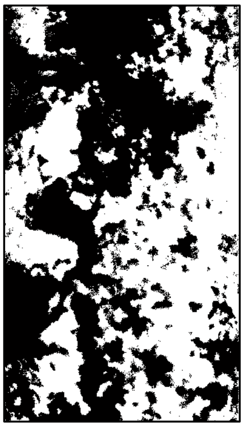

Figure 25. Black and white image of the actual RGB image (4th sample)

Figure 26. Original underwater RGB image of a sample (4th sample)

Figure 27. Black and white image of the original underwater RGB image (4th sample)

Figure 28. Improved underwater RGB image of a sample (4th sample)

Figure 29. Black and white image of the improved underwater RGB image (4th sample)

Table 4. Degree of corrosion of 4th sample as per MATLAB results

Figure	Location of image captured and image nature	Percentage of corrosion
24	On land and raw	51.4535%
26	Underwater and raw	26.8024%
28	Underwater and processed	52.9479%

Although these images are of the same sample, the estimated corrosion degree varies according to the location of image captured and image nature. Just like the 3rd sample, many information are lost when the image is taken underwater and raw. However, after undergoing the image processing, many lost information due to light scattering and colour change has been recovered although they would not be exactly the same as the image captured on land.

Another sample (5th sample) with its images taken on land and underwater are shown as below.

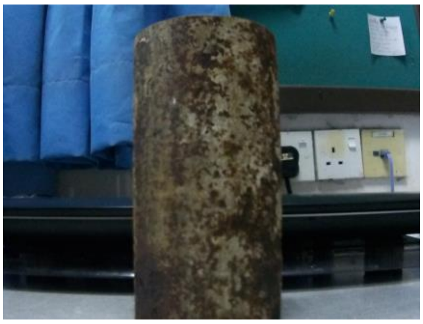

Figure 30. Actual RGB image of a sample on land (5th sample)

Figure 31. Black and white image of the actual RGB image (5th sample)

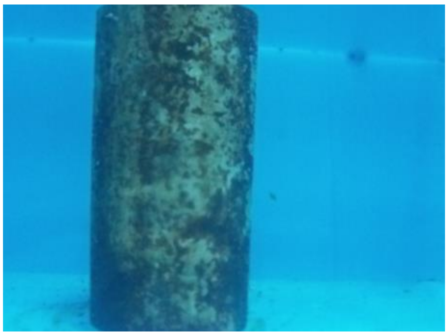

Figure 32. Original underwater RGB image of a sample (5th sample)

Figure 33. Black and white image of the original underwater RGB image (5th sample)

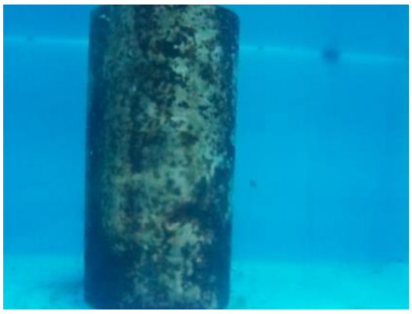

Figure 34. Improved underwater RGB image of a sample (5th sample)

Figure 35. Black and white image of the improved underwater RGB image (5th sample)

Table 5. Degree of corrosion of 5th sample as per MATLAB results

Figure	Location of image captured and image nature	Percentage of corrosion
30	On land and raw	59.4169%

32	Underwater and raw	33.3988%
34	Underwater and processed	61.1527%

Images of more sample piping and their respective results are as shown below

Table 6. Additional samples

Sample	On land and raw (corrosion degree)	Underwater and raw (corrosion degree)	Underwater and processed (corrosion degree)
6th	49.3979%	26.1321% % error = 47.1%	49.1161% % error = 0.6%
7th	75.0616%	36.9213% % error = 50.8%	68.6003% % error = 8.6%
8th	63.3265%	49.0481% % error = 22.5%	61.0536% % error = 3.6%
9th	65.5368%	46.8735% % error = 28.5%	64.1407% % error = 2.1%
10th	35.6403%	30.1796% % error = 15.3%	36.3671% % error = 2.0%

4.2 Discussions

Based on the results shown in the previous section, it can be deduced that a significant amount of information has been lost when an underwater image is taken due to light scattering and colour change in those images. After the image has been improved with hazy effect reduced and colour corrected, majority of the lost information are recovered, and thus making the estimation of degree of corrosion more reliable although they might not be totally accurate or exactly the same as the actual image of the sample.

Once the image have been captured using the underwater camera, the interested object will be remained while the background will be subtracted from the original image. An image is stored as a two-dimensional matrices in MATLAB. Every single component on the matrix represents one pixel of that image captured. As per the Workspace in MATLAB, the original image has a matrix of 2448 x 3264 x 3, which comes to show that the image contains 2448 rows and 3264 columns while the 3 represents the RGB triad. Therefore, the background of the image can be eliminated by referring to the image matrix. After some trial and error, a new image without the background is generated as the following by inputting the intended matrix as `Y= x (1:2448, 1150:2450,:);` whereby the Y is the new image and x is the original image.

Then, the RGB image will be converted to an indexed image. In the MATLAB code, the author specified it as `[z, map] = rgb2ind(Y,128);` which means that it is a 128-level index image. The number of entries, which depicts the number of significant colours need to be tried out as per suitability. If the index image is generated using too little number of levels, the image produced will be not ideal for further analysis since the colour contouring will become quite obvious will the true colour will be reduced at the same time. The difference between colour levels specified at 8 and 128 respectively are shown as below.

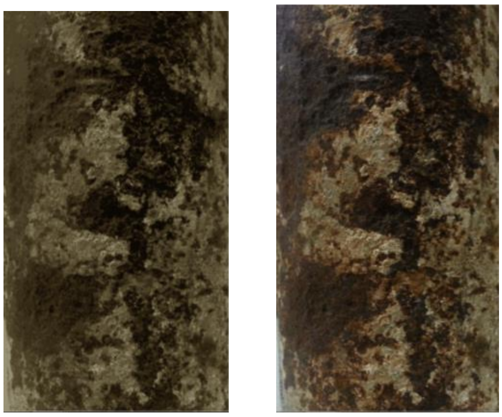

FIGURE 30. The index image on the left is of 8 levels while the 128-level indexed image is on the right.

Then from the index images, the conversion to grayscale images is done before it is converted to binary images for further analysis such as the classification based on the degree of corrosion. By using the syntax of ind2gray(z, map).

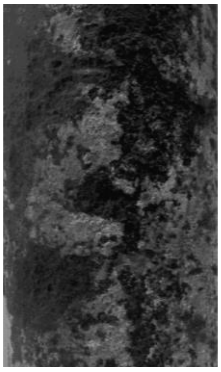

FIGURE 31. The above grayscale image can be generated from indexed images.

All images will then be converted into binary form before further analysis is carried upon them. Binary images can be produced by using the syntax of bx1 = im2bw (gz,0.3). The bx1 and gz have no specific meaning. They are just the parameter names of a binary image and grayscale image respectively. As for the 0.3, it means that the grayscale image has been converted to binary image at a threshold of 30%, which is a value obtained through trial and error. The threshold should be tried out accordingly so that the area of interest will not lose too much information during the conversion. For instance, if the threshold is too low, the resultant image will be very white because most of the grayscale will be higher than the specified limit and set to 1 as a result. On the other hand, if the threshold is set too high (for instance 90% or 0.9), the generated binary image would be having significant of dark areas as most of the grayscale values have been represented by 0 since they are lower than the threshold set by the user.

FIGURE 32. Binary image generated

After the binary images have been obtained, evaluation of the degree of corrosion can be carried out easily by calculating the fraction of black pixels (false), which are actually the corroded surface over the entire pixels involved. By obtaining the fraction, the degree of corrosion of the pipe can be shown by expressing it in percentage.

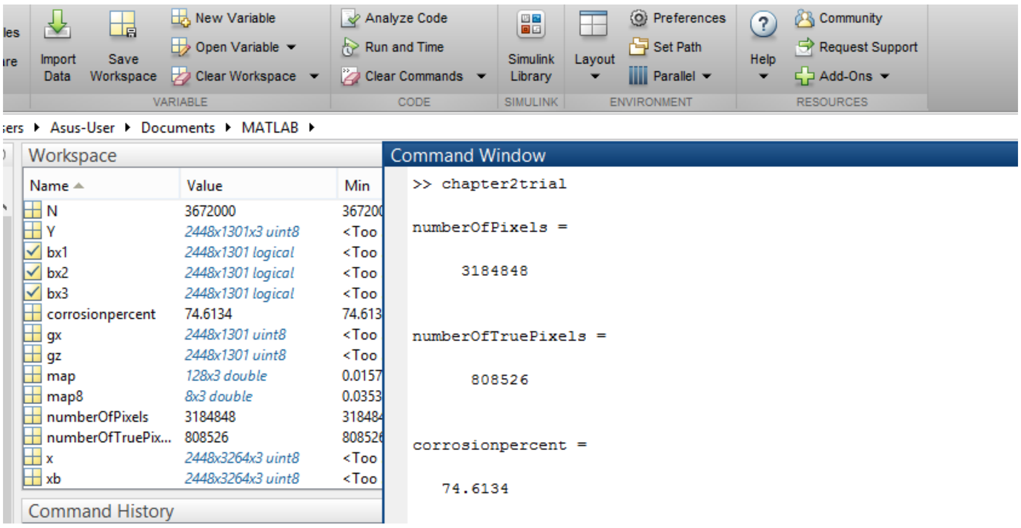

FIGURE 33. The above screenshot shows that the degree of corrosion of a pipe can be obtained from the binary image.

In an underwater image, most of the time it is dominated by blue colour because blue colour has the shortest wavelength. Using a simple physics equation of c=fλ, which is equal to c=$\frac{\lambda}{T}$, it is obvious that if the wavelength is short, the travelling time will be longer, thus blue colour travel the furthest in water and dominate underwater images.

With the processing using the proposed algorithm (WCID), the colour balance of the objects in the image is restored significantly apart from the removal of haze in the image. The hazy image equation is as shown as below.

$$I_\lambda(x) = J_\lambda(x) \cdot t_\lambda(x) + (1 - t_\lambda(x)) \cdot B_\lambda \qquad (1)$$

$I_\lambda(x)$ is the image obtained while $J_\lambda(x)$ is a scene radiance at the sample pipeline. Then, there is the term $t_\lambda(x)$ which is the residual energy ratio ($N_{rer}(\lambda)$) of the scene radiance on the sample pipeline after being reflected from the object and reaching the camera. $t_\lambda(x)$ includes the effects of light scattering and colour change happened upon the light which travels from the object to the camera. WCID starts with the derivation of the distance (d(x)) from the camera to the object (sample pipeline). Basically, dark channel prior, which is a commonly-used algorithm in image processing world to measure scene depth, is used to differentiate between background in the image and also the foreground (sample pipeline). Then, now that the background and foreground has been segregated, the distance can already be estimated.

Then, the artificial lighting has to be removed. There is no possible way to take a proper image no matter how good the camera is in a poorly-lit underwater environment. The author realized about this fact when he just started to capture underwater images of the sample piping. Therefore, artificial lighting is required while taking those underwater images. In the author's case, he used a torch light and placed it near the surface of the water to light up the container. However, the artificial lighting has to be removed to avoid any overcompensation for subsequent stages. Next, compensation of light scattering and colour change along the distance between the object and the camera has to be carried out. To eliminate the effect of light scattering, the term $(1 - t_\lambda(x)) \cdot B_\lambda$ is removed from equation (1). Then, the correction of colour change is carried out by dividing the resultant image by the $(N_{rer}\lambda^{d(x)})$, which produces equation (2).

$$J_\lambda(x) = \frac{I_\lambda(x) - (1 - N_{rer}\lambda^{d(x)}) \cdot B_\lambda}{N_{rer}(\lambda)^{d(x)}} \qquad (2)$$

To further correct the effect of colour change, compensation of colour change along the distance from the water surface to the sample piping is done by dividing the $J_\lambda(x)$ with $N_{rer}(\lambda)^{D(x)}$, which gives the author an image with restored energy and colour-corrected. With that, the resultant image is converted into binary images for the estimation of the degree of corrosion of sample pipeline.

CHAPTER 5 CONCLUSION

Light scattering and colour changes degrade underwater images. Therefore, the author aims to develop underwater image processing so that the corrected images can be used to estimate respective degree of corrosion. In conclusion, the author has managed to develop an algorithm which helps with the estimation of corrosion degree of underwater pipeline from improved underwater images.

The author has a few suggestions for the future work. For the samples, the author captured images of them using the underwater camera SJCAM 5000 instead of the HydroView MAX because of the unavailability of the underwater vehicle for an extended period. In order to further prove that this method is feasible and practical in the real world, the ROV has to be deployed to capture images of real underwater pipelines. Besides, further consideration has to be done on the presence of other bir-organisms resting on the pipeline, which might affect the estimation of the degree of corrosion as well.

On the other hand, in order to achieve the objective of the project, the author would suggest the usage of underwater cameras which are providing much higher resolution. The resolution of the built-in camera of the HydroView MAX is a bit too for effective and reliable further analysis. Therefore, underwater cameras with high resolution might be mounted on the HydroView MAX for better effects.

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