ENHANCEMENT OF UNDERWATER IMAGES USING WAVELENGTH COMPENSATION METHOD

A PROJECT REPORT

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BONAFIDE CERTIFICATE

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INTERNAL EXAMINER **EXTERNAL EXAMINER**

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ABSTRACT

Acquiring clear images in underwater environments is an important issue in ocean engineering. The quality of underwater images plays a pivotal role in scientific missions such as monitoring sea life, taking census of populations, and assessing geological or biological environments. Capturing clear images in underwater environment is challenging. Most important source of distortion in underwater environment is Haze and Hue alteration. Haze is produced because of the effect of light scattering by particle present in the underwater environment. Hue alterations occur when light enter deeper in underwater. These two issues make the image look darker and low luminosity. Haze removal and Hue altered enhancement is important for this kind of low visibility and low contrast underwater images.

Histogram equalization is used to redistribute the lightness value and contrast of an image in both RGB and HSI color spaces. Dark Channel prior effectively removes haze but color change is not processed. Both these methods are ineffective in removing the image blurriness caused by light scattering.

To overcome the hue alteration, underwater image enhancement is carried out in two steps. In the first step Haze in the underwater image is removed using dark channel prior. In the second step Hue alterations are handled by wavelength compensation. In wavelength compensation depth map is derived first and luminance of foreground and background inside the image are separated and compared. To regulate the Hue alteration wavelength can be compensated using average RGB channels in the image. After computing the scale value of each RGB component, wavelength is compensated together with the average RGB and scale value of each channel in the image.

Performance of the wavelength compensated image is evaluated using the PSNR, Focus Measurement, Contrast Improvement Index, and Feature Similarity Index. Performance measurement of the wavelength compensation produces 50% better PSNR results than the Histogram Equalization and Dark Channel Prior method.

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LIST OF ABBREVIATIONS

ICM	INTEGRATED COLOR MODEL
NR	NOISE REDUCTION
HE	HISTOGRAM EQUALIZATION
AHE	ADAPTIVE HISTOGRAM EQUALIZATION
CLAHE	CONTRAST LIMITED HISTOGRAM EQUALIZATION
DCP	DARK CHANNEL PRIOR
WCID	WAVELENGTH COMPENSATION AND IMAGE DEHAZING
MRF	MARKOV RANDOM FIELD
MAP	MAXIMUM POSTERIOR ESTIMATION
WD	WAVELENGTH DENOISING
HF	HOMOMORPHIC FILTERING
BF	BILATERAL FILTERING
FSIM	FEATURE SIMILARITY INDEX
CII	CONTRAST IMPROVEMENT INDEX
PSNR	PEAK SIGNAL TO NOISE RATIO
FM	FOCUS MEASUREMENT

CHAPTER 1

INTRODUCTION

1.1 IMAGE PROCESSING

Image processing is a method to convert an image into digital form and perform some operations on it, in order to get an enhanced image or to extract some useful information from it. It is a type of signal dispensation in which input is image, like video frame or photograph and output may be image or characteristics associated with that image [1]. Usually Image Processing system includes treating images as two dimensional signals while applying already set signal processing methods to them. It is among rapidly growing technologies today, with its applications in various aspects of a business. Image Processing forms core research area within engineering and computer science disciplines too. Image processing basically includes the following three steps.

- Importing the image with optical scanner or by digital photography.
- Analyzing and manipulating the image which includes data compression and image enhancement and spotting patterns that are not to human eyes like satellite photographs.
- Output is the last stage in which result can be altered image or report that is based on image analysis.

1.1.1 Purpose of Image processing

The purpose of image processing is divided into 5 groups. They are:

1. Visualization - Observe the objects that are not visible.
2. Image sharpening and restoration - To create a better image.
3. Image retrieval - Seek for the image of interest.
4. Measurement of pattern – Measures various objects in an image.
5. Image Recognition – Distinguish the objects in an image.

1.1.2 Types of Image Processing

The two types of **methods used for Image Processing** are **Analog and Digital** Image Processing. Analog or visual techniques of image processing can be used for the hard copies like printouts and photographs. Image analysts use various fundamentals of interpretation while using these visual techniques. The image processing is not just confined to area that has to be studied but on knowledge of analyst. Association is another important tool in image processing through visual techniques. So analysts apply a combination of personal knowledge and collateral data to image processing.

1.1.2.1 Analog Image Processing

In electrical engineering and computer science, analog image processing is any image processing task conducted on two-dimensional analog signals by analog means (as opposed to digital image processing). Basically any data can be represented in two types named as 1.Analog 2.Digital if the pictorial representation of the data represented in analog wave formats that can be named as analog image. Eg: television broadcasting in older days through the dish antenna systems. Whereas the digital representation or storing the data in digital form is termed as a digital image processing Eg:image data stored in digital logic gates.

1.1.2.2 Digital Image Processing

Digital Processing techniques help in manipulation of the digital images by using computers. As raw data from imaging sensors from satellite platform contains deficiencies. To get over such flaws and to get originality of information, it has to undergo various phases of processing. The three general phases that all types of data have to undergo while using digital technique are Pre- processing, enhancement and display, information extraction as shown in fig.1.1

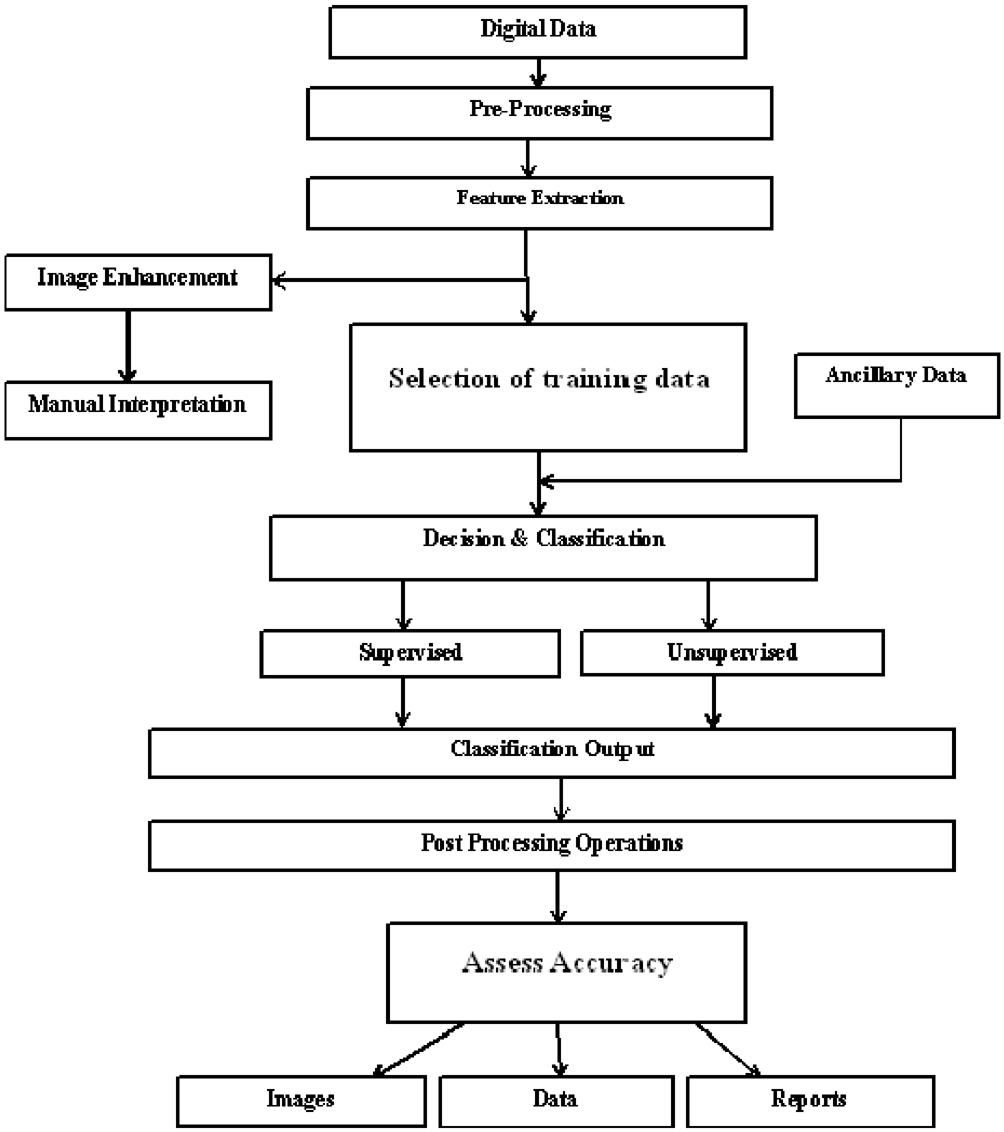


Fig.1.1 Digital Image Processing

Digital image processing is the use of computer algorithms to perform image processing on digital images. It is concerned primarily with extracting useful information from images. An image may be defined as a two-dimensional function, f(x,y) where x and y are spatial (plane) coordinates, the amplitude off at any pair of coordinates (x,y) is called intensity or grey level of the image at that point. When f, x and y are all finite and discrete quantities, the image is called a digital image. A digital image is composed of a finite number of elements, each of which has a particular location and value. These elements are referred to as picture elements, images elements and pixels. Pixel is the term most widely used to denote the elements of a digital image. Usually the image processing algorithms may be placed at three levels. At the lowest level are those techniques which deal directly with the raw, possibly noisy pixel values, with denoising and edge detection being good examples. In the middle are algorithms which utilize low level results for further means, such as segmentation and edge linking. At the highest level are those methods which attempts to extract semantic meaning from the information provided by the lower levels, for example, handwriting recognition.

The nature of the output of f(x,y) for each pixel is dependent on the type of image. Most images are the result of measuring a specific physical phenomenon, such as light, heat, distance, or energy. The measurement could take any numerical form. A greyscale image measures light intensity only. Each pixel is a scalar proportional to the brightness. The minimum brightness is called black, and the maximum brightness is called white. A colour image measures the intensity and chrominance of light. Each colour pixel is a vector of colour components. Common colour spaces are RGB (red, green and blue), HSV (hue, saturation, value), and CMYK (cyan, magenta, yellow, black). Pixels in a range image measure the depth of distance to an object in the scene.

1.1.3 Fundamental steps in image processing

1.1.3.1 Image acquisition

Image acquisition is the first process. The image acquisition stage involves pre-processing, such as scaling. Image acquisition in image processing can be broadly defined as the action of retrieving an image from some source, usually a hardware-based source, so it can be passed through whatever processes need to occur afterward. Performing image acquisition in image processing is always the first step in the workflow sequence because, without an image, no processing is possible. The image that is acquired is completely unprocessed and is the result of whatever hardware was used to generate it, which can be very important in some fields to have a consistent baseline from which to work. One of the ultimate goals of this process is to have a source of input that operates within such controlled and measured guidelines that the same image can, if necessary, be nearly perfectly reproduced under the same conditions so anomalous factors are easier to locate and eliminate.

1.1.3.2 Image enhancement

Image enhancement increases the contrast of an image. It is a very subjective area of image processing. The principal objective of image enhancement is to process a given image so that the result is more suitable than the original image for a specific application. It accentuates or sharpens image features such as edges, boundaries, or contrast to make a graphic display more helpful for display and analysis. The enhancement doesn't increase the inherent information content of the data, but it increases the dynamic range of the chosen features so that they can be detected easily.

1.1.3.3 Image restoration

Image restoration deals with improving the appearance of an image. Image restoration is objective, restoration techniques tend to be based on mathematical or probabilistic models of image degradation. Image restoration is different from image enhancement in that the latter is designed to emphasize features of the image that make the image more pleasing to the observer, but not necessarily to produce realistic data from a scientific point of view. Image enhancement techniques (like contrast stretching or de-blurring by a nearest neighbor procedure) provided by "Imaging packages" use no a priori model of the process that created the image. With image enhancement noise can effectively be removed by sacrificing some resolution, but this is not acceptable in many applications. In a Fluorescence Microscope resolution in the z-direction is bad as it is. More advanced image processing techniques must be applied to recover the object.

1.1.3.4 Color image processing

Color image processing is an area that has been gaining in importance because of the significant increase in the use of digital images over the Internet. The human visual system can distinguish hundreds of thousands of different color shades and intensities, but only around 100 shades of grey. Therefore, in an image, a great deal of extra information may be contained in the color, and this extra information can then be used to simplify image analysis, e.g. object identification and extraction based on color. Three independent quantities are used to describe any particular color. The *hue* is determined by the dominant wavelength. Visible colors occur between about 400nm (violet) and 700nm (red) on the electromagnetic spectrum. The *saturation* is determined by the excitation purity, and depends on the amount of white light mixed with the hue. A pure hue is fully saturated, i.e. no white light mixed in. Hue and saturation together determine the *chromaticity* for a given color. Finally, the *intensity* is determined by the actual amount of light, with lighter corresponding to more intense colors. *Achromatic* light has no color - its only attribute is quantity or intensity. Gray level is a measure of intensity. The *intensity* is determined by the energy, and is therefore a physical quantity. On the other hand, *brightness* or *luminance* is determined by the perception of the color, and is therefore psychological. Given equally intense blue and green, the blue is perceived as much darker than the green. Note also that our perception of intensity is nonlinear, with changes of normalized intensity from 0.1 to 0.11 and from 0.5 to 0.55 being perceived as equal changes in brightness.

1.1.3.5 Wavelets and multiresolution processing

Wavelets are the foundation for representing images in various degrees of resolution. It decomposes a signal to a sum of sinusoids; the wavelet transform decomposes a signal (image) to small waves of varying frequency and limited duration.

1.1.3.6 Compression

Compression deals with the techniques for reducing the storage required saving an image, or the bandwidth required transmitting it. This is true particularly in uses of the Internet, which are characterized by significant pictorial content. Image compression is familiar (perhaps inadvertently) to most users of computers in the form of image file extensions, such as the jpg file extension used in the JPEG (Joint Photographic Experts Group) image compression standard.

1.1.3.7 Morphological processing

Morphological process deals with extracting image components that are useful in the representation and description of shapes. It is a theory and technique for the analysis and processing of geometrical structures, based on set theory, lattice theory, topology, and random functions. Morphological image processing is a collection of non-linear operations related to the shape or morphology of features in an image. Morphological operations rely only on the relative ordering of pixel values, not on their numerical values, and therefore are especially suited to the processing of binary images. Morphological operations can also be applied to greyscale images such that their light transfer functions are unknown and therefore their absolute pixel values are of no or minor interest.

Morphological techniques probe an image with a small shape or template called a structuring element. The structuring element is positioned at all possible locations in the image and it is compared with the corresponding neighborhood of pixels. Some operations test whether the element "fits" within the neighborhood, while others test whether it "hits" or intersects the neighborhood

1.1.3.8 Segmentation

Segmentation procedures partition an image into its constituent parts or objects. In general, autonomous segmentation is one of the most difficult tasks in digital image processing. A rugged segmentation procedure brings the process a long way toward successful solution of imaging problems that require objects to be identified individually. On the other hand, weak or erratic segmentation algorithms almost always guarantee eventual failure. In general, the more accurate the segmentation, the more likely recognition is to succeed.

1.1.3.9 Representation and description

Representation and description almost always follow the output of a segmentation stage, which usually is raw pixel data, constituting either the boundary of a region (i.e., the set of pixels separating one image region from another) or all the points in the region itself. In either case, converting the data to a form suitable for computer processing is necessary. The first decision that must be made is whether the data should be represented as a boundary or as a complete region.

Boundary representation is appropriate when the focus is on external shape characteristics, such as corners and inflections. Regional representation is appropriate when the focus is on internal properties, such as texture or skeletal shape. In some applications, these representations complement each other. Choosing a representation is only part of the solution for transforming raw data into a form suitable for subsequent computer processing. A method must also be specified for describing the data so that features of interest are highlighted. Description, also called feature selection, deals with extracting attributes that result in some quantitative information of interest or are basic for differentiating one class of objects from another.

1.1.3.10 Recognition

Recognition is the process that assigns a label to an object based on its descriptors.

1.1.4 Components of image processing system

The basic component of the image processing consists of a general purpose system each component performs a function which is used for digital processing. With reference to sensing two elements are required to acquire digital images. The first is the physical device that is sensitive to the energy radiated by the object. The second is the digitizer, which is a device for converting the output of the physical sensing device into a digital form. The components of the image processing system are

1.1.4.1 Computer

The computer in an image processing system is a general-purpose computer and can range from a PC to a supercomputer. In dedicated applications, sometimes custom computers are used to achieve a required level of performance, but our interest here is on general-purpose image processing systems. In these systems, almost any well-equipped PC-type machine is suitable for off-line image processing tasks.

1.1.4.2 Specialized image processing hardware

Specialized image processing hardware usually consists of the digitizer just mentioned, plus hardware that performs other primitive operations, such as an arithmetic logic unit (ALU) that performs arithmetic and logical operations in parallel on entire images. One example of how an ALU is used is in averaging images as quickly as they are digitized, for the purpose of noise reduction. This type of hardware sometimes is called a front-end subsystem, and its most distinguishing characteristic is speed. In other words, this unit performs functions that require fast data throughputs (e.g., digitizing and averaging video images at 30 frames/s) that the typical main computer cannot handle.

1.1.4.3 Software

Software for image processing consists of specialized modules that perform specific tasks.

1.1.4.4 Mass storage

Mass storage capability is a must in image processing applications. An image of size pixels, in which the intensity of each pixel is an 8-bitquantity, requires one megabyte of storage space if the image is not compressed. When dealing with thousands, or even millions, of images, providing adequate storage in an image processing system can be a challenge. Digital storage for image processing applications falls into three principal categories :(1) short-term storage for use during processing, (2) on-line storage for relatively fast recall, and (3) archival storage, characterized by infrequent access. Storage is measured in bytes (eight bits), Kbytes (one thousand bytes), Mbytes (one million bytes), Gbytes (meaning giga, or one billion, bytes), and Tbytes (meaning tera, or one trillion, bytes).

One method of providing short-term storage is computer memory. Another is by specialized boards, called frame buffers, that store one or more images and can be accessed rapidly, usually at video rates (e.g., at 30 complete images per second). The latter method allows virtually instantaneous image zoom, as well as scroll (vertical shifts) and pan (horizontal shifts).Frame buffers usually are housed in the specialized image processing hardware unit. On-line storage generally takes the form of magnetic disks or optical-media storage. The key factor characterizing on-line storage is frequent access to the stored data. Finally, archival storage is characterized by massive storage requirements but infrequent need for access. Magnetic tapes and optical disks housed in “jukeboxes” are the usual media for archival applications.

1.1.4.5 Image displays

Image displays in use today are mainly color (preferably flat screen) TV monitors. Monitors are driven by the outputs of image and graphics display cards that are an integral part of the computer system. Seldom are there requirements for image display applications that cannot be met by display cards available commercially as part of the computer system. In some cases, it is necessary to have stereo displays, and these are implemented in the form of headgear containing two small displays embedded in goggles worn by the user.

1.1.4.6 Hardcopy

Hardcopy devices for recording images include laser printers, film cameras, heat-sensitive devices, inkjet units, and digital units, such as optical and CDROM disks. Film provides the highest possible resolution, but paper is the obvious medium of choice for written material. For presentations, images are displayed on film transparencies or in a digital medium if image projection equipment is used. The latter approach is gaining acceptance as the standard for image presentations.

1.1.4.7 An image acquisition system

An image acquisition system would be a CCD camera, a flatbed scanner, or a video recorder. Networking is almost a default function in any computer system in use today. Because of the large amount of data inherent in image processing applications, the key consideration in image processing is the bandwidth. In dedicated networks, this typically is not the problem, but communications with remote sites via the internet are not always as efficient. But it is improving quickly as a result of optical fibre and other broadband technologies.

1.1.5 Image Processing Applications

1. **Intelligent Transportation Systems** – This technique can be used in Automatic number plate recognition and Traffic sign recognition.

2. **Remote Sensing** – For this application, sensors capture the pictures of the earth's surface in remote sensing satellites or multi – spectral scanner which is mounted on an aircraft. These pictures are processed by transmitting it to the Earth station. Techniques used to interpret the objects and regions are used in flood control, city planning, resource mobilization, agricultural production monitoring, etc.

3. **Moving object tracking** – This application enables to measure motion parameters and acquire visual record of the moving object. The different types of approach to track an object are:

- Motion based tracking
- Recognition based tracking

4. **Defense surveillance** – Aerial surveillance methods are used to continuously keep an eye on the land and oceans. This application is also used to locate the types and formation of naval vessels of the ocean surface. The important duty is to divide the various objects present in the water body part of the image. The different parameters such as length, breadth, area, perimeter, compactness are set up to classify each of divided objects. It is important to recognize the distribution of these objects in different directions that are east, west, north, south, northeast, northwest, southeast and south west to explain all possible formations of the vessels. We can interpret the entire oceanic scenario from the spatial distribution of these objects.

5. **Biomedical Imaging techniques** – For medical diagnosis, different types of imaging tools such as X- ray, Ultrasound, computer aided tomography (CT) etc are used. Some of the applications of Biomedical imaging applications are as follows:

- Heart disease identification– The important diagnostic features such as size of the heart and its shape are required to know in order to classify the heart diseases. To improve the diagnosis of heart diseases, image analysis techniques are employed to radiographic images.
- Lung disease identification – In X- rays, the regions that appear dark contain air while region that appears lighter are solid tissues. Bones are more radio opaque than tissues. The ribs, the heart, thoracic spine, and the diaphragm that separates the chest cavity from the abdominal cavity are clearly seen on the X-ray film.

- Digital mammograms – This is used to detect the breast tumour. Mammograms can be analyzed using Image processing techniques such as segmentation, shape analysis, contrast enhancement, feature extraction, etc.

6. **Automatic Visual Inspection System** – This application improves the quality and productivity of the product in the industries.

- Automatic inspection of incandescent lamp filaments – This involves examination of the bulb manufacturing process. Due to no uniformity in the pitch of the wiring in the lamp, the filament of the bulb gets fused within a short duration. In this application, a binary image slice of the filament is created from which the silhouette of the filament is fabricated. Silhouettes are analyzed to recognize the non uniformity in the pitch of the wiring in the lamp. This system is being used by the General Electric Corporation.

- Automatic surface inspection systems – In metal industries it is essential to detect the flaws on the surfaces. For instance, it is essential to detect any kind of aberration on the rolled metal surface in the hot or cold rolling mills in a steel plant. Image processing techniques such as texture identification, edge detection, fractal analysis etc are used for the detection.

- Faulty component identification – This application identifies the faulty components in electronic or electromechanical systems. Higher amount of thermal energy is generated by these faulty components. The Infra-red images are produced from the distribution of thermal energies in the assembly. The faulty components can be identified by analyzing the Infra-red images.

1.2 IMAGE ENHANCEMENT

The purpose of image enhancement is to "improve" images in terms of the visual appearance for human interpretation and also the suitability for subsequent computer processing. The main objective of image enhancement is to process a given image so that the result is more suitable than the original image for a specific application. It accentuates or sharpens image features such as edges, boundaries, or contrast to make a graphic display more helpful for display and analysis. The enhancement doesn't increase the inherent information content of the data, but it increases the dynamic range of the chosen features so that they can be detected easily.

Types

1. Spatial domain enhancement method
2. Frequency domain enhancement method

1.2.1 Spatial domain enhancement method

Spatial domain techniques are performed to the image plane itself and they are based on direct manipulation of pixels in an image. The operation can be formulated as $g(x,y) = \mathbf{T}[f(x,y)]$, where g is the output, f is the input image and $\mathbf{T}$ is an operation on f defined over some neighbourhood of (x,y). According to the operations on the image pixels, it can be further divided into 2 categories: Point operations and spatial operations (including linear and non-linear operations).

$$G(x,y)=f(x,y)*h(x,y) \tag{1.1}$$

1.2.2 Frequency domain enhancement method

Frequency method enhance an image $f(x,y)$ by convoluting the image with a linear, position invariant operator. The 2D convolution is performed in frequency domain with DFT.

$$G(w1, w2) = F(w1, w2)\, H(w1, w2) \tag{1.2}$$

1.2.3 Enhancement by point processing

These processing methods are based only on the intensity of single pixels.

1.2.3.1 Simple intensity transformation

(a)Image negatives

Negatives of digital images are useful in numerous applications, such as displaying medical images and photographing a screen with monochrome positive film with the idea of using the resulting negatives as normal slides. The transformation function is expressed in Eqn.1.3.

$$\text{Transform function T: } g(x,y)=L-f(x,y), \qquad (1.3)$$

Where L is the maximum intensity

(b)Contrast stretching

Low-contrast images can result from poor illumination, lack of dynamic range in the image sensor, or even wrong setting of a lens aperture during image acquisition. The idea behind contrast stretching is to increase the dynamic range of the grey levels in the image being processed.

(c) *Compression of dynamic range*

Sometimes the dynamic range of a processed image far exceeds the capability of the display device, in which case only the brightest parts of the images are visible on the display screen. An effective way to compress the dynamic range of pixel values is to perform the following intensity transformation function

$$s = c \log (1+|r|) \qquad (1.4)$$

Where c is a scaling constant and the logarithm function performs the desired compression.

(d) *Gray-level slicing*

Highlighting a specific range of gray levels in an image often is desired. Applications include enhancing features such as masses of water in satellite imagery and enhancing flaws in x-ray images.

1.2.3.2 Histogram processing

The histogram of a digital image with gray levels in the range [0, L-1] is a discrete function

$$P (r_k)=n_k/n, \qquad (1.5)$$

where r_k is the k^{th} gray level, n_k is the number of pixels in the image with that gray level, n is the total number of pixels in the image, and k=0,1..L-1.P(r_k) gives an estimate of the probability of occurrence of gray level r_k. The shape of the histogram of an image gives useful information about the possibility for contrast enhancement.

(a)Histogram equalization

The objective is to map an input image to an output image such that its histogram. It is uniform after the mapping. Let *r* represent the gray levels in the image to be enhanced and *s* is the enhanced output with a transformation of the form *s*=**T**(*r*).

(b)Histogram specification

Histogram equalization generates an approximation to a uniform histogram. Sometimes the ability to specify particular histogram shapes capable of highlighting certain gray-level ranges in an image is desirable.

(c)Local enhancement

It is often necessary to enhance details over small areas. The number of pixels in these areas may have negligible influence on the computation of a global transformation, so the use of global histogram specification does not necessarily guarantee the desired local enhancement.

1.2.4 Spatial Filtering

A spatial filter is an image operation where each pixel value I(u, v) is changed by a function of the intensities of pixels in a neighbourhood of (u, v).

1.2.4.1 Smoothing filter

Smoothing filters are used for blurring and for noise reduction. Blurring is used in pre-processing steps, such as removal of small details from an image prior to object extraction, and bridging of small gaps in lines or curves. Noise reduction can be accomplishing by blurring with a linear filter and also by nonlinear filtering.

(a)*Low pass filtering*

The key requirement is that all coefficients are positive. Neighbourhood averaging is a special case of LPF where all coefficients are equal. It blurs edges and other sharp details in the image.

(b)*Median filtering*

If the objective is to achieve noise reduction instead of blurring, this method should be used. This method is particularly effective when the noise pattern consists of strong; spike-like components and the characteristic to be preserved is edge sharpness. It is a nonlinear operation.

1.2.4.2 Sharpening Filters

To highlight fine detail in an image or to enhance detail that has been blurred, either in error or as a natural effect of a particular method of image acquisition. Uses of image sharpening vary and include applications ranging from electronic printing and medical imaging to industrial inspection and autonomous target detection in smart weapons.

1.2.5 Enhancement in the frequency domain

The Fourier transform of the image to be enhanced is computed by multiplying the result by a filter transfer function, and take the inverse transform to produce the enhanced image.

1.2.6 Pseudo color image processing

In automated image analysis, color is a powerful descriptor that often simplifies object identification and extraction from a scene. Human eye performs much better in discerning shades of color than gray scale. A monochrome image can be enhanced by using colors to represent different gray levels or frequencies. In pseudo color image processing the gray level to colour transformation can be performed by changing the phase and frequency of each sinusoid can emphasise in color ranges in the grey scale. The peak means the constant color region and the valley means the rapid changed color region. A small change in the phase in the transforms produces little change in pixels whose gray level corresponds to the peak in sinusoidal. Pixels with gray level values in the steep section of the sinusoids are assigned much stronger.

CHAPTER 2

UNDERWATER IMAGES

Acquiring clear images in underwater environments is an important issue in ocean engineering [11], [12]. The quality of underwater images plays a pivotal role in scientific missions such as monitoring sea life, taking census of populations, and assessing geological or biological environments. Capturing images underwater is challenging, mostly due to haze caused by light that is reflected from a surface and is deflected and scattered by water particles, and color change due to varying degrees of light attenuation for different wavelengths [13]–[15]. Light scattering and color change result in contrast loss and color deviation in images acquired underwater as shown in Fig.2.1. Light rays bend when they travel from one medium to another; the amount of bending is determined by the refractive of the two media. If one medium has a particular curved shape, it functions as a lens. The cornea, humours, and crystalline lens of the eye together form a lens that focuses images on the retina. Our eyes are adapted for viewing in air. Water, however, has approximately the same refractive index as the cornea effectively eliminating the cornea's focusing properties. When our eyes are in water, instead of focusing images on the retina, they now focus them far behind the retina, resulting in an extremely blurred image from hyper metopic.

Haze is caused by suspended particles such as sand, minerals, and plankton that exist in lakes, oceans, and rivers. As light reflected from objects propagates toward the camera, a portion of the light meets these suspended particles. This in turn absorbs and scatters the light beam, as illustrated in Fig.2.1. In the absence of blackbody radiation [16], the multi-scattering process along the course of propagation further disperses the beam into homogeneous background light.

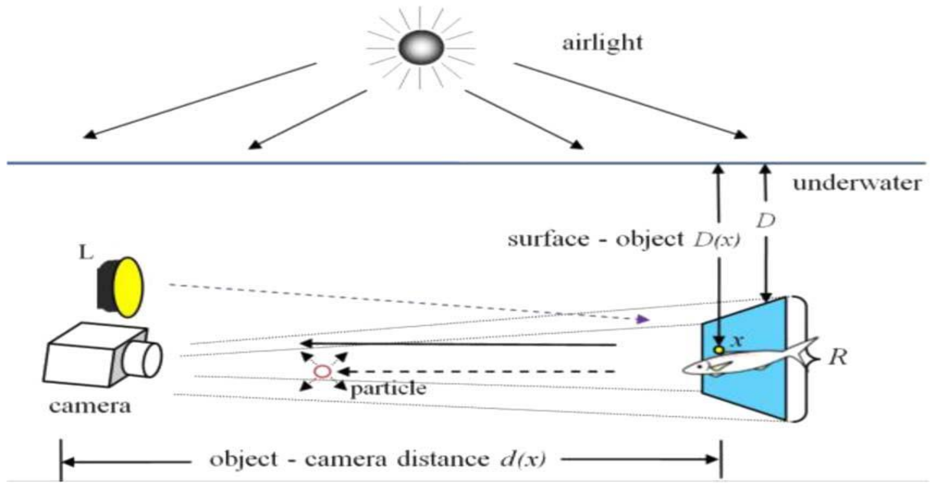


Fig. 2.1 Natural lights enters from air to an underwater scene point

2.1 Color Vision in Underwater

Water has a significantly different refractive index to air, and this affects the focusing of the eye. Most animals' eyes are adapted to either underwater or air vision, and do not focus properly when in the other environment. Water attenuates light due to absorption which varies as a function of frequency. In other words, as light passes through a greater distance of water color is selectively absorbed by the water. Color absorption is also affected by turbidity of the water and dissolved material.

Water preferentially absorbs red light, and to a lesser extent, yellow, green and violet light, so the color that is least absorbed by water is blue light. Particulates and dissolved materials may absorb different frequencies, and this will affect the color at depth, with results such as the typically green color in many coastal waters, and the dark red-brown color of many fresh water rivers and lakes due to dissolved organic matter.

Table.2.1. Light Absorption in Underwater

Color	Average Wavelength	Approximate Depth of Total Absorption
Ultraviolet	300 nm	25m
Violet	400nm	100m
Blue	475nm	275m
Green	525nm	110m
Yellow	575nm	50m
Orange	600nm	20m
Red	685nm	5m
Infrared	800nm	3m

Underwater image processing techniques and methodologies have been developed to improve quality of underwater images. Alternative identified problem is relating to density of water than air light. In underwater environment light rays travels to the water and it gets reflected and deflected multiple times. Aggregate of light is degraded when light propagates deeper in water. And hence color wavelengths are plunged one by one. Color wavelengths dropped off when light rays goes deeper in water on their wavelength. At the depth of 3m red color has disappeared. At the further depth orange and yellow colors goes off. Finally green and purple disappeared [18].

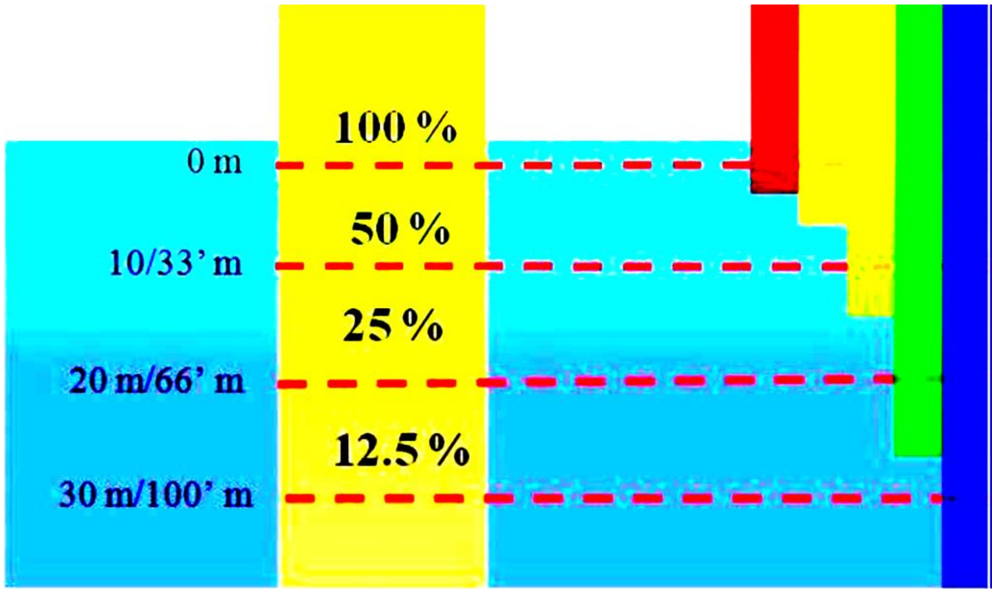


Fig 2.2 Appearance of Color Model in Underwater

Disappearance of color wavelength in underwater is shown in Fig.2.2. Blue color has shortest wavelength and hence it travels longer distance in water. This wavelength propagation makes an image full domination of blue color. In underwater environment blue color has dominated than other color.

2.2 Image Dehazing

When one takes a picture in foggy weather conditions, the obtained image often suffers from poor visibility. The distant objects in the fog lose the contrasts and get blurred with their surroundings. This is because the reflected light from these objects, before it reaches the camera, is attenuated in the air and further blended with the atmospheric light scattered by some aerosols (e.g., dust and water-droplets). Also for this reason, the colors of these objects get faded and become much similar to the fog, the similarity of which depending on the distances of them to the camera.

The image dehazing is essentially an under-constrained problem. The general principle of solving such problems is therefore to explore additional priors or constraints. Following this idea, we begin our study in this paper by deriving an inherent boundary constraint on the scene transmission. This constraint, combined with a weighted L_1-norm based contextual regularization between neighbouring pixels, is formalized into an optimization problem to recover the unknown transmission. Our method requires only a few general assumptions and can restore a haze-free image of high quality with faithful colors and fine edge details.

2.3 Noise Reduction

Due to the impurities and the special illumination conditions, underwater images are noisy. The Removing noise while preserving edges of an input image enhances the sharpness and may be accomplished by different strategies such as median filtering, anisotropic diffusion and bilateral filtering. However, for videos this task is more challenging since both spatial and temporal coherence need to be taken into account. The bilateral filter is one of the common solutions being a non-iterative edge-preserving smoothing filter that has proven useful for several problems such as tone mapping, mesh smoothing and dual photography enhancement.

2.4 Methodology

Image enhancement is a technique of improving the quality of image by improving its feature and its RGB values. The underwater image processing area has received considerable attention within the last decades, showing important achievements. The some of the basic methodology that have been specifically developed for the underwater environment.

- Contrast enhancement
- Contrast Stretching
- Color Model
- Filtering
- Dehazing
- Wavelength Compensation

These methods are capable of extending the range of underwater image processing, improving image contrast level and resolution quality.

2.5 Objective

The main objective of the underwater image enhancement is to compensate the light scattering and color change effects in underwater environment.

- Light scattering effect which is caused due to light incident on objects reflected and deflected multiple times by particles present in the water before reaching the camera. This in turn lowers the visibility and low contrast of an image.
- Another important problem is color change which corresponds to the varying degrees of attenuation encountered by light traveling in the water with different wavelengths, rendering ambient underwater environments dominated by a bluish tone.

CHAPTER 3

LITERATURE SURVEY

There are several methods to improve underwater image enhancement techniques, the processing of underwater image captured is necessary because the quality of underwater images affect and these image leads some serious problems when compared to images from a clearer environment. A lot of noise occurs due to low contrast, poor visibility conditions (absorption of natural light), non-uniform lighting and little color variations, pepper noise and blur effect in the underwater images because of all these reasons number of methods are existing to cure these underwater images different filtering techniques are also available in the literature for processing and enhancement of underwater images one of them is image enhancement using median filter which enhances the image and help to estimate the depth map and improve quality by removing noise particles with the help of different techniques, and the other is RGB Color Level Stretching have used. Forward USM technique can also be used for image enhancement.

Saibabu and Vijayan [2] introduced an Adaptiveand Non Linear Technique for Enhancement of Extremely High Contrast Images for some extremely bright and dark regions in the night images. Authors found that some previous methods worked well for dark images and some for bright images, but not worked well for both type of images. So they used three methods such as adaptive intensity enhancement, contrast enhancement and color restoration to make the algorithm more adaptable to the image characteristics

Alexander Wong and William [3] presented a new perceptually-adaptive technique for enhancement of information within still images for persons who were suffering from dichromacy. They applied a non-linear hue remapping method to the still images for improving color differentiation while preserving the visuals of the images by stretching dynamic range of red-green or blue-yellow colors of images. Authors observed that previous techniques did not preserve the visual of the original color image. So they gave this new technique for producing enhanced images that preserve visual detail along with maintain the aesthetics of the original image.

Iqba and et al [4] proposed Unsupervised Color Correction Metho. Underwater images are affected by low contrast and non-uniformity due to scattering of light rays in the underwater environment. For the enhancement of underwater image quality they proposed unsupervised color correction method (UCM). This approach is established on color matching, color model of RGB and HSI contrast improvement. First step of UCM is equalization of color cast. Second step is to improve low contrast underwater image when color change can be concentrated. Red color histogram is enlarged towards maximum similarly concentration of blue color has been stretched towards minimum value. Finally HSI color model have been used for contrast adjustment to rectify the original color image using Hue and Saturation and also difficulty of radiance is reported through intensity.

Prabhakar C.J., Praveen Kumar P.U. [5] developed a technique on Image Based Enhancement of Underwater Image. Field of investigation is involved for underwater images. To capture data such as coral reefs remotely operated vehicles and autonomous underwater vehicles are used. Generally underwater images are essentially characterized by their bad visualization. Light is very poor propagated as it propagates through water and the output signals resulting poorly contrasted and haze or fog like in nature. Absorption and scattering causes light fading, efficiency of underwater signal processing system is affected as its result. The image blurred because of forward scattering.

Shuai Fang and et al.[6] researched on Effective Single Underwater Image Enhancement by Fusion technique. Easer Poor quality of underwater image is: light fading which increases the contrast and another one is color change to get back the distorted color to normal. With fewer occurrences light absorption and scattering takes part, then length and wavelength propagates the medium, this causes off set of color. Where else, poor light intensity is faced due to the light absorption effect.

Amine Mahiddine and et al. [7] has been worked on SIFT and SURF. In air medium or water medium light crosses and it is component are reflected back, in effect the rest is perforates into water. Underwater images are darker with increasing depth. The strength of light intensity is reduced along with depth, but also the light undergoes color change depending on the amount of water. The pre-processing of underwater image can be denoted by: image restoration algorithm. This algorithm consists of two parts. The first one is adjusting the chromatic data. In this method the pixels are processed based on the content of the image. The second case deals with the restoration and enhancement of colors in the output image. Scale invariant feature transform "SIFT" is a technique for extracting points of interest that are unchanged to changes during image acquisition which are underwater in nature, these points of interest are of Gaussians (DoG). Each point has tribute a descriptor vector which is having exact way of the gradient in the region. This involves; the first classification is given to the detection of points of interest, where local maxima are calculated for every scaling using the matrix formations. From these, the candidate points the given minimum which will subsequently be invariant to scaling are identified.

Cosmin Ancuti and et al.[8] worked on Fusion technique. The mid-level values of the basic color channels are equalized to obtain color combined and exact images. The input color images of the underwater level are balanced. The histograms performance of linear adjustment at preprocessing level is done by stretching the original mean value to the desired mean value of the frames. The luminance gain is saved by luminance map in the final frame. In nature visualization the general appearance is flat and weight value represents the deviation between every R, G and B color channels. Pixels such as edges and texture, etc., yields high values by contrast weight map to image molecules. This generates the map dependence on an effective contrast indicator. A filter described on the grayscale of input needed to be there. To control the gain the result value Chromatic weight map is used. This map is a simple indicator. It calculates every pixel. Using a Gauss curve the distance between the saturation value and the maximum of the saturation range is done and observed.

Junxuan and Ke Zhang [9] described Adaptive Color Restoration and Luminance Based Multi Scale Retinex Scheme to improve the visual quality of color images under poor lighting condition. They declared that Red, Green, Blue color bands improved by amending luminance which automatically enhanced to a proper range based on Human Visual System using the adaptive parameter. Authors found in the previous research that A luminance based Multi-scale Retinex improved darker images in the poor lightening areas along with saving CPU time largely, but it doesn‟t work in other images as effectively as „darker objects with brighter background‟ in the images and „whole black background‟ images. So they improved the previous Luminance Based Multi Scale Retinex by extended into Adaptive Color Restoration Luminance Multiscale retinex to achieve better visual results by perceiving more details and without varying percentage of R, G, and B in the three bands.

N. M. Kwok and et al. [10] demonstrated local sector enhancement technique to address the problems such as to preserve the color information content while enhancing the contrast and image quality by making use of local contrast information and fusing the enhanced image with the original. They introduced that enhanced sectors were modulated by a Gaussian mask to mitigate unexpected changes at the sector boundaries. Local sectors with higher contrast dominated the others thus achieving overall global contrast enhancement. They claimed performance of this approach was evaluated by using a collection of color images taken under dissimilar conditions. Authors had found some limitations in previous research that had been exposed in global histogram equalization approaches including unnatural artifacts produced and loss of object details.

Kota and et al. [11] studied that HE caused an effect on brightness, shadow in some almost homogeneous area. So to control enhancement degree and maintain brightness, they proposed two methods such as HE with variable enhancement degree and Brightness preserving Bi-HE with Variable Enhancement Degree which are extended version of HE and Brightness Preserving Bi-HE respectively. They claimed that later method realized the natural enhancement and permitted some different mean brightness between the original image and the enhanced image.They introduced Modified Histogram Equalization for Image Contrast Enhancement method in which the image histogram is divided into two parts and after that two histograms are independently equalized.

Fan Yang, Jin Wu [12] introduced an improved image contrast enhancement based on HE, which is especially suitable for multiple-peak images. They found some disadvantages in previous research that some algorithms increased contrast of the images but they usually produce certain undesirable effects in the results. So they claimed that new method presented an efficient algorithm in achieving widely dynamic range and improving contrast of the images. They applied Gaussian filter for removing noise in images and the valley values of the image histogram divided the original histogram into different areas. Histogram equalization method applied on each segment separately. They also proved that present method was better than as compared with HE and Bi-HE.

Deepak and Joonwhoan Lee [13] introduced a Nonlinear Transfer Function-Based Local Approach for Color Image Enhancement method for enhancing the color image in which pixel neighborhood method and overlapped window based method applied on only V component of the Hue Saturation Value color image, but H and S component are not changed to prevent the degradation of color balance between HSV components. Authors found in previous research that HVS and compressed Discrete Cosine Transform domain method enhanced both dark and bright region of an image equally well but not enhance all parts of the image very well. A local approach was applied on V components instead of global approach. Luminance all over the image was not same, some regions may be dark or bright so the image locality was to be considered while enhancing.

M. C. Hanumantharaju and et al. [14]: introduced a new algorithm and architecture suitable for Field Programmable Gate Array implementation of adaptive color image enhancement based on Hue-Saturation-Value color space. By stretching dynamic range, the saturation component was enhanced to get rich color display. In order to avoid color alteration, Hue was retained. They found in previous research that traditional arithmetic mean filter tends to lose image detail such as edges and sharpness when compared to geometric mean filter and reconstructed quality of image using this scheme was generally not satisfactory. So an adaptive luminance enhancement was attained by using a simple geometric mean filter instead of arithmetic mean filter and also used to achieve very good quality reconstructed images. For speed up the enhancement process, Pipelining and parallel processing techniques had been adapted.

Apurba and Ashish [15] introduced Particle Swarm Optimization based hue preserving color image enhancement technique to improve image quality by maximizing the details in the input image and to solve the optimization problem. They stated that parameterized transformation function used to enhance the quality of the intensity image, in which parameters were optimized by Particle Swarm Optimization based on an objective function. This function also used local and global information of the input image and the objective function considers the entropy and edge information to measure the image quality. They found that algorithm gave better results as compared with Hue-Preserving Color Image Enhancement without gamut problem and a Genetic Algorithm based approach to Color Image Enhancement.

Zhiyuan and et al. [16] introduced Example based Dist-Stretched contrast enhancement algorithm to enhance the image contrast effectively. They described problems of traditional HE methods and also stated that resulted images from this method had more natural looking than those of traditional HE based methods. So they proposed classical version of HE that used globally redistribute pixel values in the stretched dynamic range by creating a linear cumulative histogram. Therefore, by studying the associated properties of the histogram of the example image, the target image enhanced towards similar visual appearance of the example image. They described the basic principle of the ExDS algorithm that the target and the example images share similar scene or tonal distributions.

Yi-Sheng Chiu and et al [17] introduced an Efficient Contrast Enhancement Using Adaptive Gamma Correction and Cumulative Intensity Distribution method in which an automatic transformation technique used to improve the brightness of dimmed images based on the gamma correction and probability distribution of the luminance pixel. They firstly described histogram analysis which provided the spatial details of the single image based on probability and statistical inference. Authors stated the weighting distribution for smoothing and gamma correction for enhancing. They claimed that it provided better contrast based on the comparison with previous research techniques which didn't attain the proper balance between the image trend preservation and the image enhancement.

Junjun and et al [18] introduced a novel Modified Multiscale Contrast Enhancement technique based on manipulating the Discrete Cosine Transform coefficients was an improved version of previous methods. They proposed a technique that used an image contrast measure Second-Derivative-like Measure of Enhancement to choose the optimal parameters and to demonstrate the effectiveness of the methods. Authors stated that proposed method behaved low frequency and high frequency coefficients differently to suppress the block artifacts and protect large edge details in the low frequency components. Alpha rooting and logarithmic enhancement function to the band enhancement provided high flexibility to modify the Discrete Cosine Transform coefficients and also provided more balanced results than applying the individual techniques alone.

Rajib Kumar and et al. [19] introduced a internal noise induced contrast enhancement of dark images in which Dynamic Stochastic Resonance was applied on DCT coefficient iteratively to enhance the image energy by making a energy transition into another state, or with inter-well transition of a particle in a bistable double well system. They found that present method gave least iteration in comparison others techniques and due to adaptive sub block selection or Dynamic Stochastic Resonance, it enhanced very dark as well as low contrast images very effectively with negligible loss of information at the bright areas. It was not only adjusted the background illumination but also improve contrast while preserving enhancing color information.

Farhan and et al. [20] introduced a Weighted Average Multi Segment HE method using Gaussian filter which applied on original images for preserving mean brightness and reducing noise. They found that the brightness of the input image shifted to the mid gray level and failed to preserve brightness. Some previous techniques preserved brightness but introduced undesirable artifacts. They declared that mean brightness of processed image located in the middle of the input mean and the middle gray level and Weighted Average Multi Segment HE was a hybrid form of three methods such as Multi Peak HE with Brightness Preserving method, Minimum Within-Class Variance Multi HE and Recursive Mean-separate HE. These three methods provided better results together.

H. D. Cheng and Yingtao Zhang [21] focused that Over-enhancement lead to the loss of edges, textures, fine details, and unnatural images which was the major problem of image contrast enhancement algorithms. They claimed that a novel method which investigated analyzed and detected reasons of over-enhancement and located the over enhanced areas accurately and effectively, and provided a quantitative criterion. They found that there was no accurate, effective method for detecting over enhancement yet. But without a good detection method, it affected and hampered the development of image enhancement techniques greatly. Authors also stated that to avoid over-enhancement, some algorithms controlled the intensity range of the processed images but the major drawback of was under-enhancement which made some parts of the images enhanced insufficiently. Some algorithms studied the performance of the enhancement only using the contrast ratio without investigating and discussing the over enhancement; therefore, the results often had serious over-enhancement separation measure. They claimed that over-enhancement was detected if the value of SMO was greater than a threshold T.

Kashif Iqbal and et al [22] proposed an Integrated Color Model. In consideration to light reflection, the lights reflection changes distinctly based on the sea structure. Another main contemplation is related to the water, that bends the light either to make patterns crinkle or to disseminate it. The filtering properties of the water, then quality of the water are controlled and determines sprinkle of the dust in water. The amount of light is polarized and reflected. Then it partly enters water vertically. Most notable characteristic of the vertical polarization is that it decides the object less shining. This property helps to capture primary colors. These primary colors may not be possible to capture it. The technological assumption to sea research, the problem of enhancement is increased gradually. Important issue is to improve the quality of the images is to contour processing analysis of the image. Underwater images related issues arise from the light absorption and scattering effects. The applied bimodal histogram model is designed for the images in order to enhance the underwater image; they applied by using contrast stretching techniques. They categorize the image into two forms; object and background and then applied segmentation method.

John Y and et al. [23] developed a technique on Wavelength Compensation and Dehazing. Where light scattering and color modify are two main sources of alteration for underwater shooting. Light scattering is affected by light event on objects reflected and deflected many times. This in turn lowers the visibility and contrast of the image captured. Color change corresponds to the unstable degrees of reduction encountered by light traveling in the water with diverse wavelengths, depiction ambient underwater environments conquered by a bluish quality. No obtainable underwater processing techniques can handle light dispersion and color change distortions caused by underwater images, and the probable presence of false lighting concurrently. This literature proposed a novel systematic come up to to improve underwater images by a de-hazing algorithm, to give back the attenuation difference along the broadcast path, and to take the pressure of the possible presence of a false light source into consideration. Distances between the objects and the camera, is expected; the foreground and background within a view are segmented. By managing the effect of artificial light, the haze occurrence and inconsistency in wavelength attenuation along the underwater broadcast path to camera are corrected. Secondly, the water deepness in the image scene is predictable according to the remaining energy ratios of diverse color channels obtainable in the background light.

Survey of different techniques of underwater image enhancement is to enhance the quality of underwater images and different techniques used Color Stretching & USM filter both on RGB to enhance underwater images. The approached used i.e. median filter [13] which is used to estimate the transmission of input image. The atmospheric light is obtained by using dark channel prior. Further improvement a color correction quality is employed to enhance the color contrast of the object in underwater and remove different noise particles. In order to increase the efficiency of underwater images and improve the quality and to get more sharper and accurate images, as per the study in the future we can work in the sequence of the existing methods for underwater images make more clearer and sharper that the use USM filtering technique USM which will help to reduce complexity of the system and also addresses the problem of color levels. Survey of underwater image enhancement technique is summarized in below Table 3.1.

Table.3.1. Survey on Underwater Image Enhancement

AUTHOR	TITLE	APPROACH	RESULTS
Iqbal, K.; Odetayo, M.; James, A.; Salam, R.A.; Talib, A.Z.H.	Enhancing The Low Quality Images Using Unsupervised Color Correction Method	Unsupervised Color Correction Method (UCM).	Better Illumination Enhancement and Contrast
Prabhakar C.J., Praveen Kumar P.U.	An Image Based Technique for Enhancement of Underwater Images	Filter Techniques	Easily diagnoised and Unwanted Distortions are Removed
Shuai Fang, Rong Deng, Yang Cao, Chunlong Fang	Effective Single Underwater Image Enhancement by Fusion	Single Image Enhancement Based On Fusion Strtegy	Provides Greater Accuracy and Contrast level
Amine Mahiddine, Julien Seinturier, Jean-Marc Boï, Pierre Drap, Djamal Merad	Performances Analysis Of Underwater Image Preprocessing Techniques On The Repeatability Of SIFT And SURF Descriptors	SIFT and SURF Descriptors	Grander Efficiency and Accuracy
Cosmin Ancuti, Codruta Orniana Ancuti, Tom Haber, Philippe Bekaert	Enhancing Underwater Images By Fusion	Multi-Scale Fusion Principles	Images with Greater Quality
John Y. Chiang and Ying-Ching Chen	Underwater Image Enhancement by Wavelength Compensation and Dehazing	Artificial Light Removal and Wavelength Compensation	Improves the Visual Quality of an Image

CHAPTER 4

PROPOSED METHOD

In underwater photographic system, the light transmitted from a subject is absorbed and scattered in the medium before it reaches the camera [11]. This is due to the presence of fine suspended particles such as sand, minerals and plankton that exist in lakes, oceans and rivers. This process causes degraded photographs and often lack visual vividness and appeal. In underwater photography the two major sources of distortions are light scattering and color change. Haze is due to Light scattering occurs when individual photons of light are reflected or diverted when they encounter suspended particles in the water. Haze is removed using the method of Dark Channel Prior. Color change corresponds to the varying degrees of attenuation for different wavelength [24]. The wavelength of the underwater image is compensated using Wavelength Compensation method.

4.1 DARK CHANNEL PRIOR

Dark channel prior method is can produce a natural haze-free image together with a good depth map. However, because this approach is based on a statistically independent assumption in a local patch, it requires the independent components varying significantly. Any lack of variation or low signal-to-noise ratio (e.g., in dense haze region) will make the statistics unreliable. Moreover, as the statistics is based on color information, it is invalid for grayscale images and difficult to handle dense haze which is often colorless and prone to noise.

We summarize our main contributions as follows:

- The Separating an image into diffuse and specular components is an ill-posed problem due to lack of observations.

- The observed color of an image is formed from the spectral energy distributions of the light reflected by the surface reflectance, and the intensity of the color is determined by the imaging geometry.
- The dark channel is taken from the lowest intensity value among RGB channels at each pixel.

The Dark Channel Prior method approach is physically valid and is able to handle distant objects even in the heavy haze image. It does not rely on significant variance on transmission or surface shading in the input image. The result contains few halo artifacts. Like any approach using a strong assumption, our approach also has its own limitation. The dark channel prior may be invalid when the scene object is inherently similar to the air light over a large local region and no shadow is cast on the object.

4.1.1 Color Feature Extraction

A color image is a combination of some basic colors. In each individual pixel of a color image (termed 'true color') down into Red, Green and Blue values. We are going to get as a result, for the entire image is 3 matrices, each one representing color features. The three matrices are arranging in sequential order, next to each other creating a 3 dimensional m by n by 3 matrixes. Color Feature extraction is illustrated in fig 4.1 followed by below four steps.

Step1: Three color planes namely Red, Green and Blue are separated.

Step2: For each plane row mean and column mean of colors are calculated.

Step3: The average of all row means and all columns means are calculated for each color plane.

Step4: The features of all 3 planes are combined to form a feature vector. Once the feature vectors are generated for all images in the database, they are stored in a feature data set.

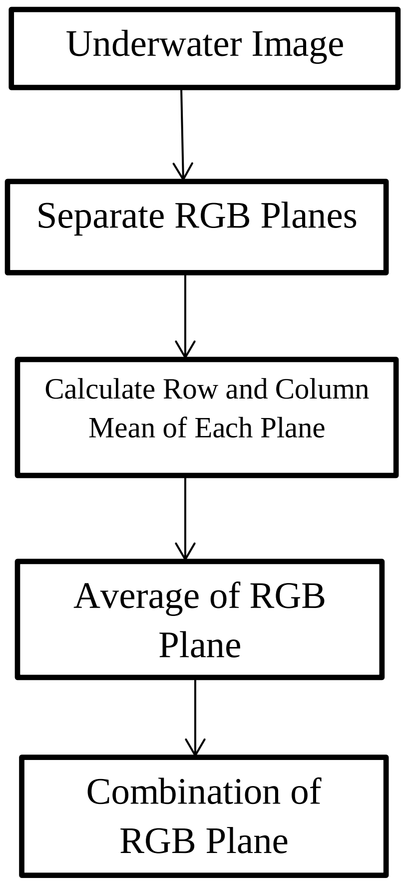


Fig 4.1 Color Feature Extraction

4.1.2 Estimating the Light Source of Illumination

The underwater image color constancy algorithms are based on simplifying assumptions such as restricted (limited number of image colors which can be observed under a specific illuminant), the distribution of colors that are present in an image (*e.g.* white patch) and the set of possible light sources. The dimensions should be Px3, where P is the number of data points and 3 is the number of color channels.

To estimate the color of the light source to compute the canonical range's for the light illumination type (i.e., pixels, Edges and Gradient). For accurate performance, the canonical range must be learned using images that are a representative set of real-world surfaces. Also, all images that are used to learn the canonical range must be images that are illuminated by the same light source. To take illumination from all directions into account, let us consider an infinitesimal patch of the extended light source, of an image size.

The Color transmission algorithm is based on the average reflectance in a scene under a neutral light source is achromatic. In these two algorithms are proven to be important instantiations of the Minkowski-norm:

$$L_C(P) = (\int F_C^P(x)dx)^{\frac{1}{p}} = ke_c \quad (4.1)$$

Where c = {R, G, B} and k is a multiplicative constant chosen such that the illuminant color, e = $(e_R, e_G, e_B)^T$, has unit length.

4.1.3 Dark Channel

The dark channel prior is based on the following observation on haze-free outdoor images: in most of the non-sky patches, at least one color channel has very low intensity at some pixels. In other words, the minimum intensity in such a patch should has a very low value. Formally, for an image *I*, we define

$$I^{dark}(x) \min_{c\in\{r,g,b\}} \left(\min_{y\in\Omega(x)} \left(I^c(y)\right)\right) \quad (4.2)$$

Where I_c is a color channel of *I* and Ω(x) is a local patch centered at *x*. Our observation says that except for the water color region, the intensity of *I* dark is low and tends to be zero, if *I* is a haze-free underwater image.

The low intensities in the dark channel are mainly due to three factors: a) shadows. e.g., the shadows of leaves, trees and rocks in landscape images;b) colorful objects or surfaces. e.g., any object (for example, green grass/tree/plant, red or yellow flower/leaf, and blue water surface) lacking color in any color channel will result in low values in the dark channel; c) dark objects or surfaces. e.g.,dark tree trunk and stone. As the natural outdoor images are usually full of shadows and colorful, the dark channels of these images are dark.

4.1.4 Dehazing Using Dark Channel Prior

The dark channel prior relies on sample minima; it is especially sensitive to outliers. Various approaches can be taken to robustly estimate the dark channel, and by extension the transmission map, considering the presence of noise. The hazy image prior to performing the dehazing process is a natural approach to handling the problem of noise in underwater scene radiance recovery. This will be the case with most standard dehazing algorithms, since they typically treat the noise level as homogeneous throughout the underwater image, and we know that noise in the recovered scene radiance is inversely proportional to the spatially varying transmission.

In our restoration scheme, dehazing as a pre-processing step is especially convenient considering that it is already necessary for estimating the atmospheric light and transmission map. In the dehazing step, we can treat our image model as: $Y = I + n$, with the task being only to estimate I, which encapsulates the hazy image. After the hazy image is dehazed, the rest of the dehazing process is exactly the same as in the noise-free case. The complete dehazing procedure is summarized in Algorithm 1 and shown in fig 4.2.

Algorithm 1: Underwater Image Haze and Noise Removal via Dark Channel Followed by Dehazing

1. Estimate I by Color models contrast variation in input image Y

2. Estimate transmission, t, and atmospheric light, a_{∞} (e.g. dark channel prior) from I

3. Dehaze I through inversion of Eq. (1) to obtain the restored image: the scene radiance estimate R.

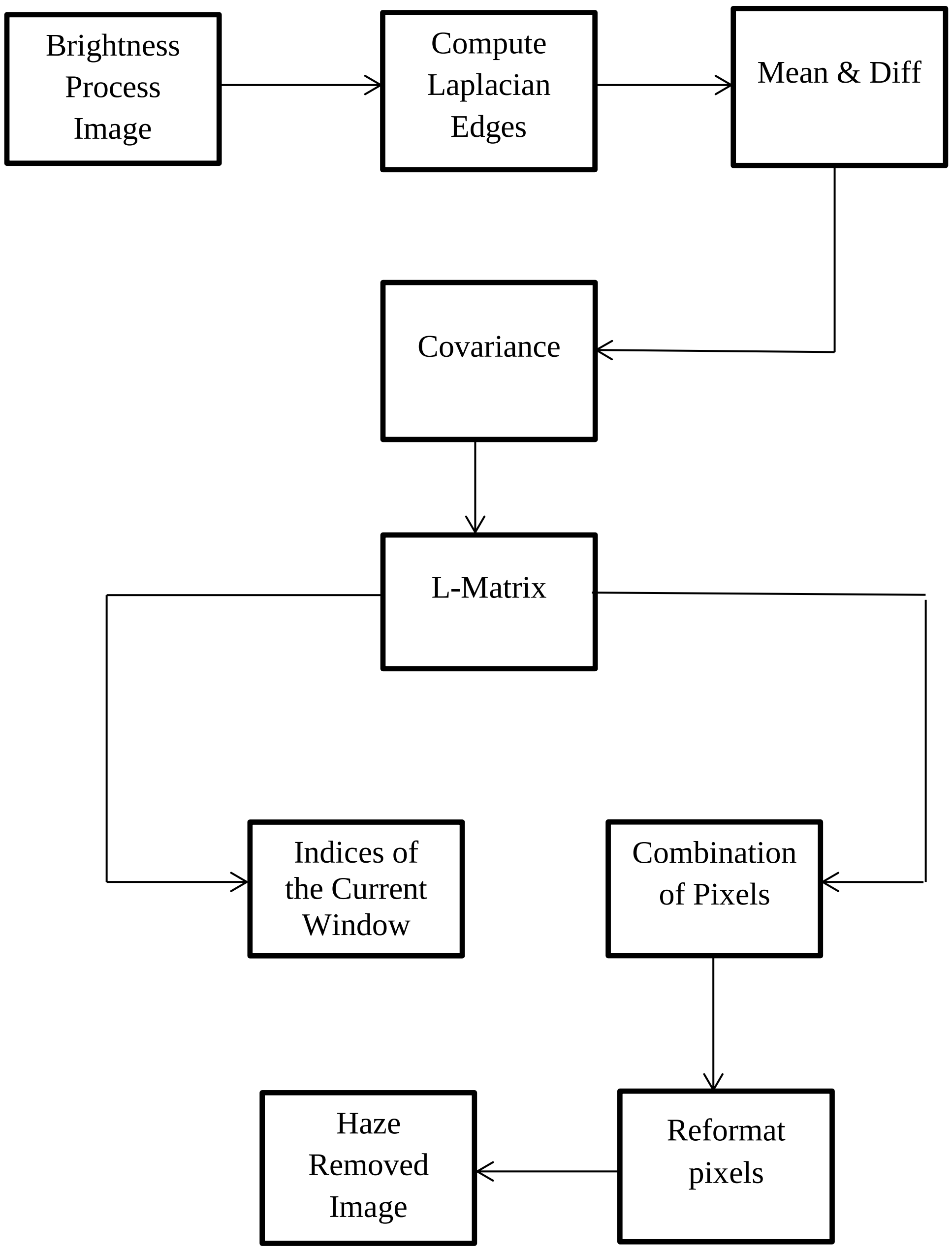


Fig 4.2 Haze Removal Process

4.1.5 Architecture Diagram for Dark Channel Prior

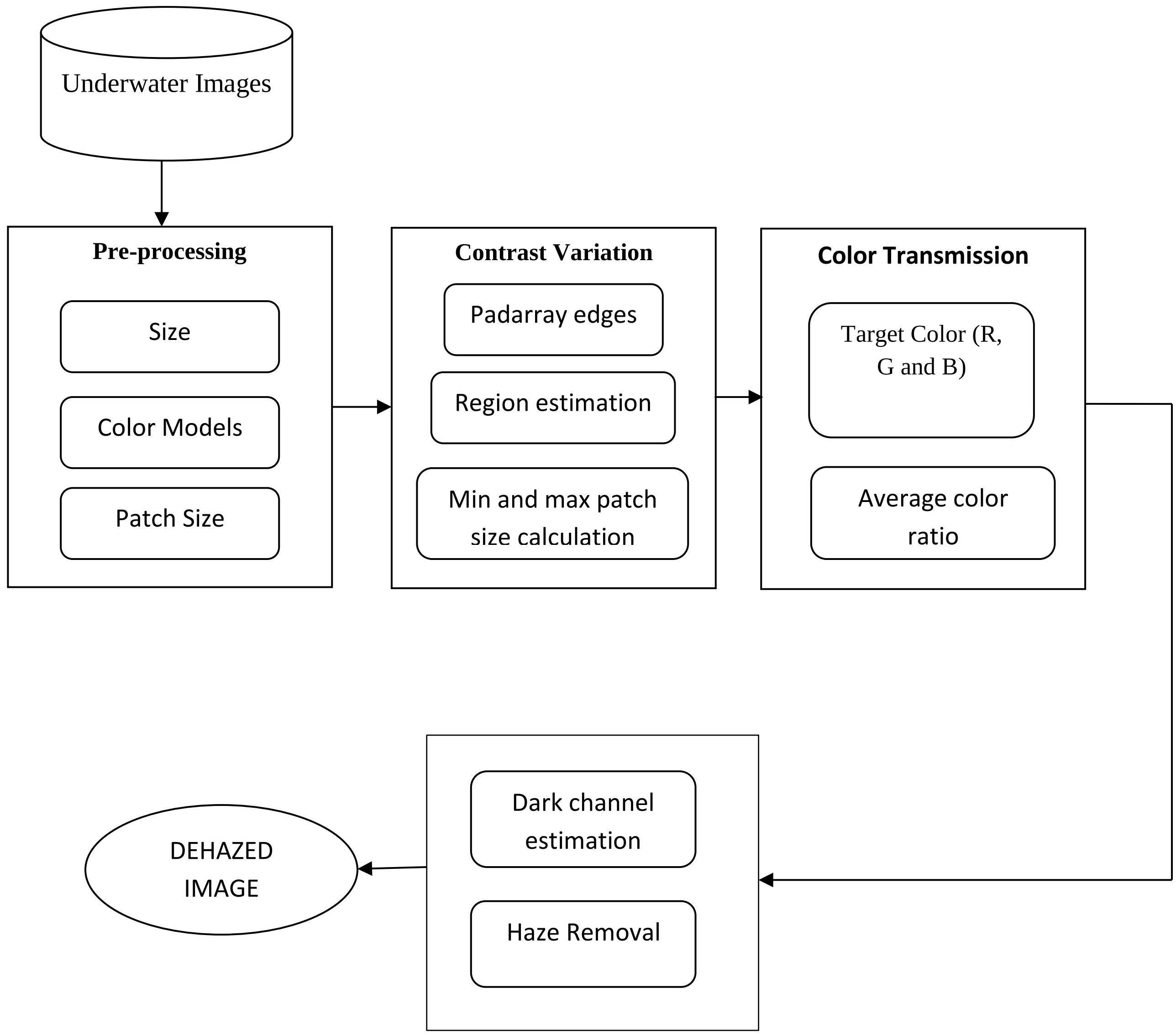
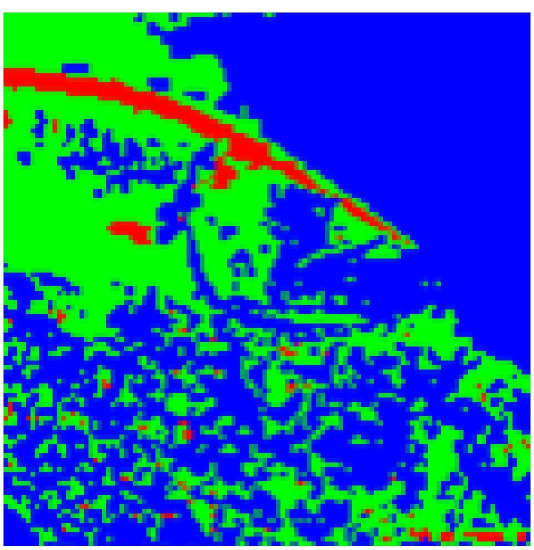


Fig.4. Dehazing Process

4.1.6 Simulation Results of Dark Channel Prior Method

(a) Input Image

(b) Dark Channel



(c) RED, GREEN, BLUE Variation

(d) Foreground Images

Fig.4.4 Underwater Image After Processing with Dehazing Method of Dark Channel Prior Algorithm

4.2 WAVELENGTH COMPENSATION

In Low Complexity Wavelength Compensation and Image Dehazing Algorithm first the distances between scenes objects to camera is estimated by using a low complexity Dark Channel Prior Algorithm. Based on the depth map derived the foreground and background area within the image is segmented [27]. The light intensities of foreground and background are then compared, to determine whether an artificial light source is employed during the image acquiring process. If an artificial light source is detected, the added luminance is to be eliminated. The Wavelength Compensation and Image Dehazing algorithm are utilized to remove the haze effect and color change along the underwater propagation path.

The underwater photographic system is provided with an artificial light source in addition to flash light of camera for avoiding the insufficient lighting in photographic environment [23]-[29]. The light from both the camera and artificial light source is incident on surface points in the scene and reflected back to camera. In the propagation path between the subject and camera d(x), hazing and color distortion occurs due to light scattering and varying degrees of attenuation encountered with different wavelength of light. The homogeneous skylight entering above into the water is the major source of illumination in an underwater environment.

4.2.1 Architecture Diagram for Wavelength Compensation

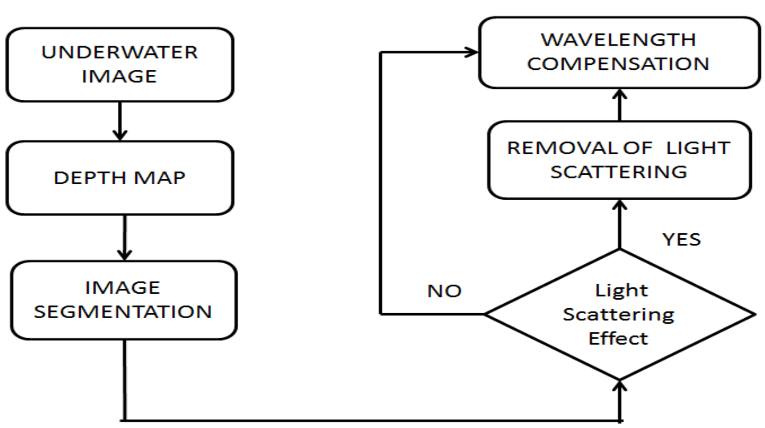


Fig 4.5 Wavelength Compensation

In wavelength compensation the distance between objects to camera is estimated by using Dehazing algorithm. Based on the depth map the foreground and background area within the image is segmented. The foreground and background light intensities of the image are then compared, to determine whether an artificial light source is employed during the image acquiring process, the added luminance is to be eliminated by detecting the artificial light source. The Wavelength Compensation algorithm is utilized to remove the haze effect and color change along the underwater propagation path.

4.2.2 Depthmap

The dark channel, which is an existing scene depth derivation method, is based on the fact that, in most of the non-background light patches on a haze free underwater image, at least one color channel has a very low intensity at some pixels. The minimum intensity in such a patch should have a very low value, called a dark channel. Pixels with a very low value cannot be found in the local patch, which implies the existence of haze. The concentration of haze can be quantified by dark channel prior algorithm. This in turn provides the object camera distance, i.e. the depth map. The underwater hazy image can be modelled by using the Radiative Transport equation,

$$I\lambda\ (x) = j_{\lambda}(x).t\lambda(x) + (1-t_{\lambda}(x))\ .\ B_{\lambda} \tag{4.3}$$

Where $\lambda \in$ {red,green,blue}

Here „x" is a point on the underwater scene, $I\lambda$ (x) is the image captured by the camera, $j\lambda(x)$ is the scene radiance at point x ie the actual amount of light source reflected from point x, $t\lambda(x)$ is the residual energy ratio of $j\lambda(x)$ after reflecting from point x in the underwater scene before reaching the camera. $B\lambda$ is the homogeneous background light and λ is the light wavelength. The residual energy ratio is a function of both the wavelength λ and the object camera distance d(x). The direct attenuation $j_{\lambda}(x)$. $t_{\lambda}(x)$ describes the decay of scene radiance in the water. The dark channel can be calculated by using the equation,

$$\text{Darkchannel} = \min (I_{\lambda}(x)) \qquad (4.4)$$

Where $\lambda \in$ {red,green,blue}

$U_{\lambda}(x)$ is the submerged image captured by camera. The background light $B\lambda$ is usually assumed to be the pixel intensity with the highest brightness value in an image. The brightest pixel value among all local minima corresponds to the background light as follows,

$$B_{\lambda} = \max (\min (U_{\lambda}(x))) \qquad (4.5)$$

The deepness estimation can be calculated by using the formula.

$$\text{Depth map} = 1\text{-}\min \{\text{median} (J_{\lambda}(x))/B_{\lambda}\} \qquad (4.6)$$

The median filter is used to smoothing technique.

4.2.3 Image Segmentation

Based on the depth map derived, the foreground and background areas within the image are segmented. The light intensities of foreground and background are then compared to determine whether an artificial light source is employed during the image acquiring process. If an artificial light source is detected, the luminance introduced by the auxiliary lighting is removed from the foreground area to avoid over compensation.

The existence of an artificial light source can be determined by comparing the difference between the mean luminance of the foreground and the background. In an underwater image without artificial lighting, the dominant source of light originates from the air light above the water surface. The underwater background corresponds to light transmitted without being absorbed and reflected by objects and is therefore the brighter part of the image. Higher mean luminance in the foreground of an image than that in the background indicates the existence of a supplementary light source. The foreground and the background of an image can be segmented as shown in fig. 4.6.

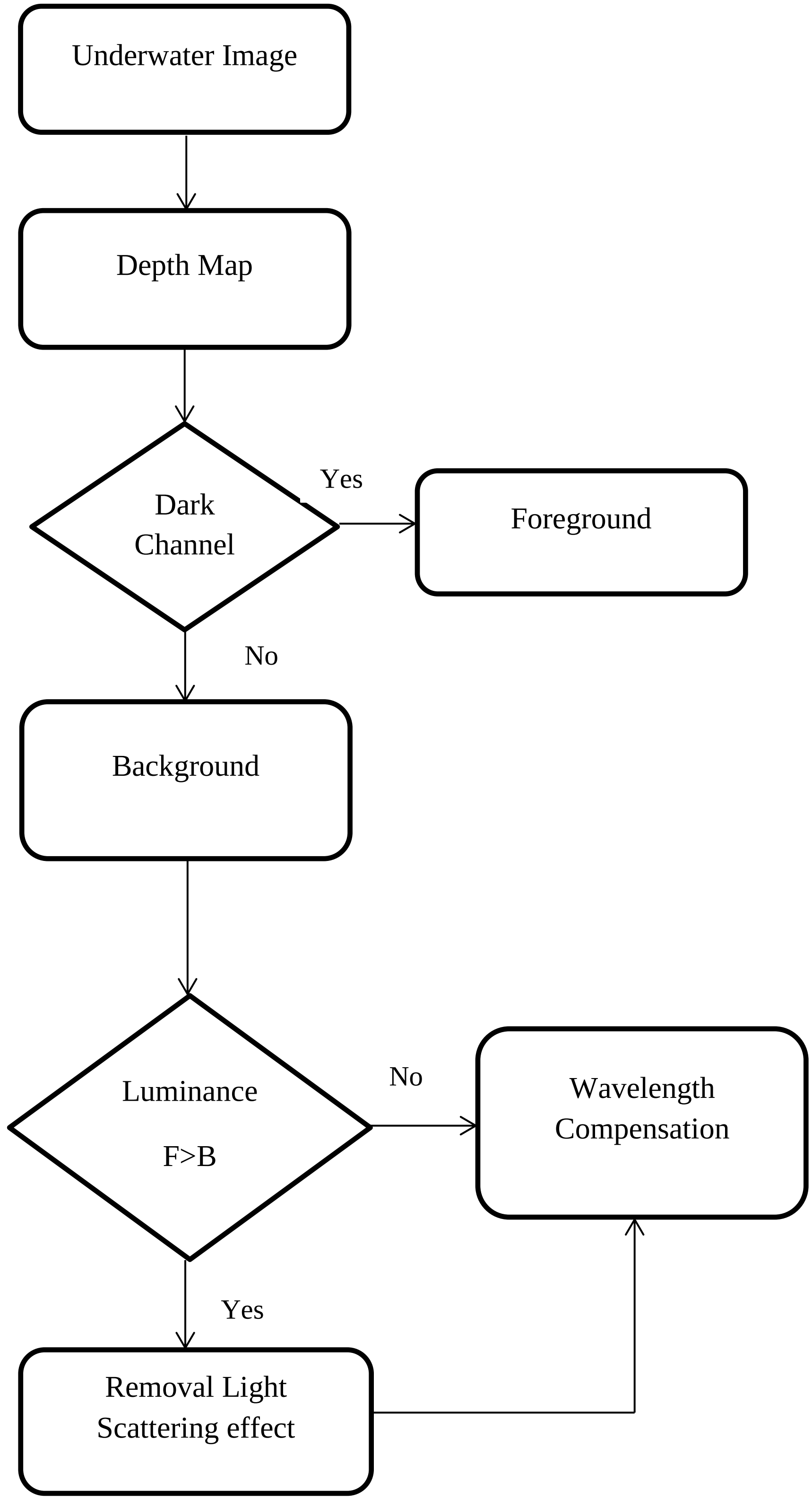


Fig.4.6 Image Segmentation

Initially the image is considered and segmented at foreground and background using depth map. Then luminance value is estimated at both foreground and background. When the luminance is comparatively high at foreground than that of background it is generally stated to be less scattering. If less scattering is determined it should be removed by updating the foreground and background luminance value. Images. Then wavelength compensation method is adopted.

4.2.4 Wavelength compensation

Aim of this proposed algorithm is to Haze removal and compensate the Hue altered image wavelength as shown in fig 4.7. Wavelength compensation consists of following steps.

Step 1: Compute average value of R, G, and B components.
Step 2: Gray value is the average of R, G, and B average.
Step 3: Calculate scale value for each component using equation (4.7)

$$\begin{aligned} &R\_Scale\ value = Gray\ value / R\_Avg \\ &G\_Scale\ value = Gray\ value / G\_Avg \\ &B\_Scale\ value = Gray\ value / B\_Avg \end{aligned} \tag{4.7}$$

Step 4: Estimate wavelength compensated R,G,and B component using equation (4.8)

$$\begin{aligned} &WC\_R = R\_Scale\ value * Im(R) \\ &WC\_G = G\_Scale\ value * Im(G) \\ &WC\_B = B\_Scale\ value * Im(B) \end{aligned} \tag{4.8}$$

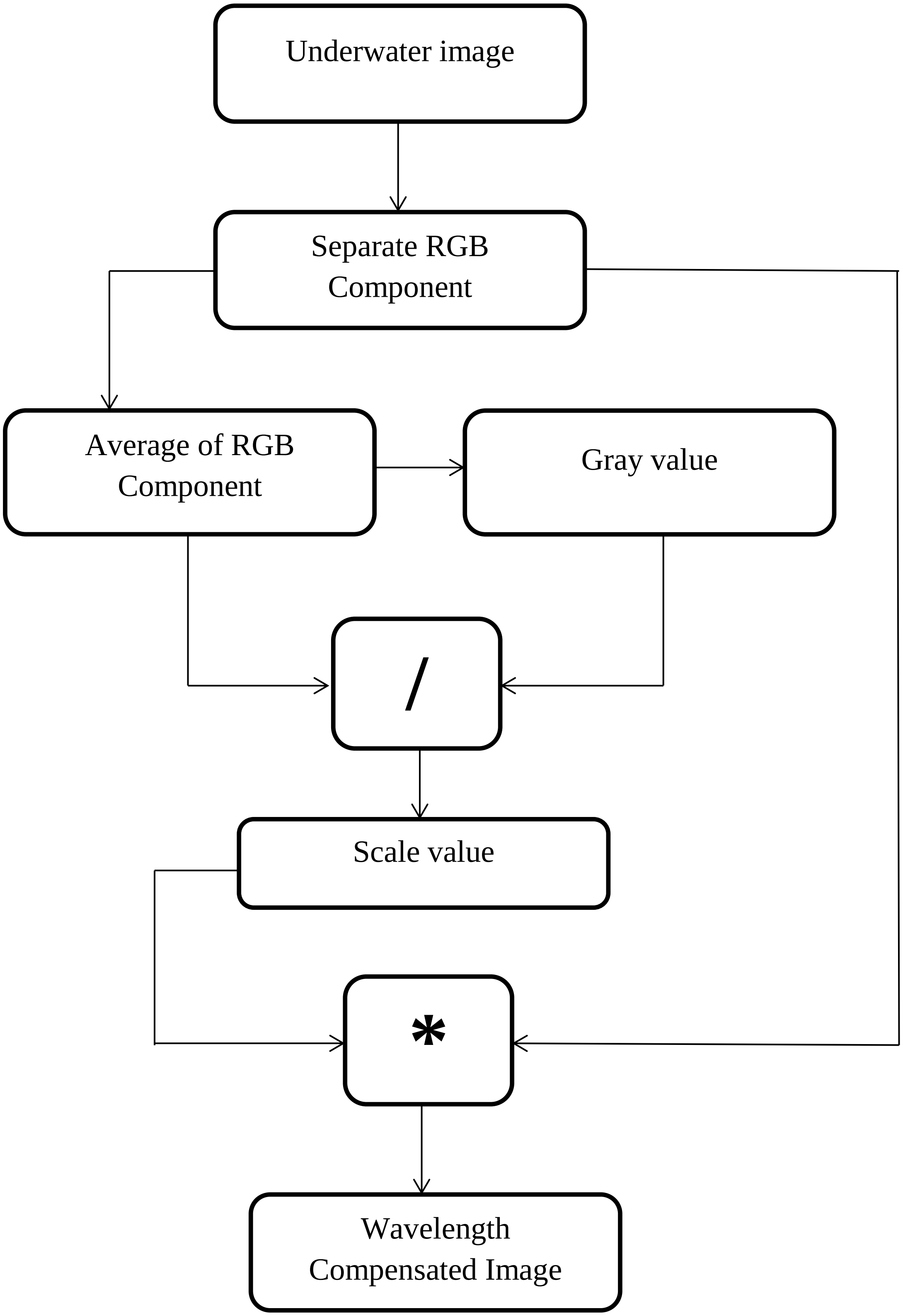


Fig.4.7. Wavelength Compensation of Underwater Image

4.2.5 Simulation Results of Wavelength Compensation Method

(a) Input Image

(b) Dark Channel

(c) Depth Map Image

(d) Foreground Images

(e) Background Images

(f) Wavelength Compensated Image

Fig.4.8 Underwater Image after Processing with Wavelength Compensation

CHAPTER 5

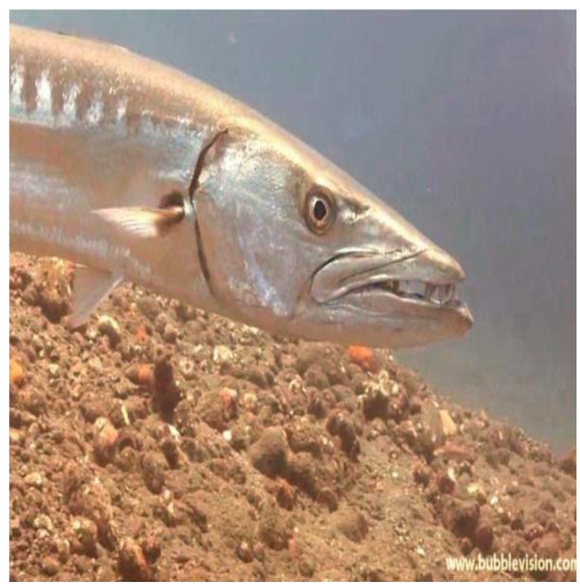
RESULTS AND DISCUSSION

The Dehazing algorithm of Dark Channel Prior can effectively restore image and remove haze. A very simple but powerful prior is called dark channel prior, for underwater image haze removal. The dark channel prior is based on the statistics of the underwater images. Applying the prior into the haze imaging model, haze can be effectively removed. After processing the dehazing process haze can be effectively removed but color change is still exist in the dehazed underwater image. However, the salinity and the amount of suspended particles in ocean water vary with time, location, and season, making accurate measurement of the rate of light energy loss is difficult [30]. Errors in the rate of light energy loss will affect the precision of both the water depth and the underwater propagation distance.

Another important problem of underwater enhancement is to correcting the color change. The wavelength compensation method is to overcome the color change and light scattering effect removal. To the best of our knowledge, no existing techniques can handle light scattering effect and color change distortions suffered by underwater images simultaneously. Once the underwater depths for all pixels are obtained, the restored energy of the underwater image after haze removal and calibration of color change can be modified to better compensate the energy loss during light propagation along different water depths by dividing average value of RED, GREEN, and BLUE of underwater image.

The experimental results demonstrate superior haze removing and color balancing capabilities of the proposed algorithm over traditional dehazing and histogram equalization methods and shown in Fig 5.1. Performance of these enhancement methods analysed.

(a) **(b)**



(c) **(d)**

Fig 5.1 Underwater enhancement resultant images (a) Underwater Input Image after Processing with (b) Histogram Equalization, (c) Dark Channel Prior, (d) Wavelength Compensation

5.1 PERFORMANCE ANALYSIS

The performance measure for enhancement of the image can be determined by means of measuring its contrast improvement index, feature similarity index measurement, PSNR and Focus Measurement as shown in Table.3.

5.1.1 PSNR

The Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR) are the two error metrics used to compare image compression quality. The MSE represents the cumulative squared error between the compressed and the original image, whereas PSNR represents a measure of the peak error [1].

To compute the PSNR, the block first calculates the mean-squared error using the following equation:

$$MSE=\frac{\sum_{M,N}[I_1(m,n)-I_2(m.n)]^2}{M*N} \tag{5.1}$$

In the previous equation, *M* and *N* are the number of rows and columns in the input images, respectively. Then the block computes the PSNR using the following equation:

$$PSNR=20\log_{10}\left(\frac{MAX}{\sqrt{MSE}}\right) \tag{5.2}$$

5.1.2 Tenengrad (Focus Measurement)

In order to evaluate the effectiveness of the resultant image a well-known benchmark-image focus measure. The tenengrad criterion is based on gradient, at each pixel*(x, y)*, where the partial derivatives are obtained by a high-pass filter, eg., The gradient magnitude is given by: sobel operator, with the convolution kernels[35]

$$S(x, y) = \sqrt{i_x * i(x,y)^2 + i_y * i(x,y)^2} \tag{5.3}$$

And the tenengrad criterion is formulated as

$$TEN=\sum_x \sum_y s(x,y)^2 > T \tag{5.4}$$

Where T is the threshold, the quality of the image is usually considered better if its tenengrad value is higher.

5.1.3 Contrast Improvement Index (CII)

A quantitative measure of contrast improvement is calculated using contrast improvement index (CII) [35]. Contrast improvement index can be found by using following equation.

$$CII = C_{enhanced} / C_{original} \tag{5.5}$$

Where $C_{enhanced}$ denotes the contrast values for the region of interest in the enhanced image and $C_{original}$ denotes the contrast values for the region of interest in the original images respectively. The contrast C in the image is defined in Equation (5.6).

$$C = max-min/max+min \tag{5.6}$$

5.1.4 Feature Similarity Index Measurement (FSIM)

The feature-similarity (FSIM) index is proposed based on the fact that human visual system (HVS) understands an image mainly according to its low-level features [37]. Specifically, the phase congruency (PC), is used as the primary feature in FSIM and the image gradient magnitude (GM) is employed as the secondary feature in FSIM. $S_{PC}(x)$, $S_G(x)$ be the similarity measure for phase congruence and gradient magnitude and $S_I(x)$, $S_Q(x)$ be the similarity between chromatic features. $PC_m(x)$ is the maximum of $PC_1(x)$ and $PC_2(x)$. The FSIM can be found by using the equation (5.7).

$$FSIM = \frac{\sum_\Omega S_{PC}(x).\ S_G(x).\ [S_I(x).S_Q(x)]^\lambda PC_m(x)}{\sum_\Omega PC_m(x)} \tag{5.7}$$

FSIM will be defined and computed based on PC_1, PC_2, G_1 and G_2.Specifically, the phase congruency (PC), which is a dimensionless measure of the significance of a local structure, is used as the primary feature in FSIM. Considering that PC is contrast invariant while the contrast information does affect HVS' perception of image quality, the image gradient magnitude (GM) is employed as the secondary feature in FSIM. PC and GM play complementary roles in characterizing the image local quality.

TABLE 5.1 Performance Analysis for Underwater Images

Enhancement Method	**PSNR**	**FM**	**CII**	**FSIM**
Histogram Equalization	16.256dB	1.3417e+004	1.6724	0.8076
Dark Channel Prior	25.4306dB	3.5868e+008	1.7387	0.82112
Wavelength Compensation	43.086dB	5.5482e+008	1.9820	0.9979

CHAPTER 6

CONCLUSION

The underwater image suffers from low contrast and resolution due to modest visibility surroundings, consequently object identification become typical mission. The underwater image enhancement of hazy and hue altered images using Wavelength compensation algorithm is to compensate various degree of attenuation along the propagation path, and influence of light scattering effect considered. In this project the impact of the light scattering effect is removed from the underwater image. For removing the influence of light scattering effect, initially the deepness of the image map is derived. Based on the depth map derivation the image is segmented to foreground and background images. Then the presence of light scattering effect is detected by comparing the mean luminance of foreground and background images. If the luminance of foreground is greater than the background, then there exists an artificial light source. If the presence of light scattering effect is detected then the influence of it is eliminated from the hazed underwater image. Then wavelength of underwater image is compensated in two steps. 1) Calculating average of each RGB component in the image. 2) Scale value is calculated from the computed average RGB channel. The haze effect and hue alteration can be effectively removed by using Wavelength Compensation algorithm. The evaluation of the wavelength compensation algorithm is evaluated for underwater images. Wavelength Compensation provides 45% better enhancement than the Dark Channel Prior and 60% than the existing contrast enhancement of Histogram Equalization and underwater videos downloaded from youtube. Results demonstrate hue alteration removing of the wavelength compensation algorithm over dark channel prior.

CHAPTER 7

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