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Under Water Image Enhancement Using Adaptive Retinal Mechanism

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Abstract- Underwater image restoration is a difficult task due to the shortage of reference image and changing underwater environment. The images are distorted by absorption and scattering effect of light. In deep water, light undergoes wavelength-dependent attenuation. Thus, red color light that has a large wavelength attenuates more than blue light and any other color. As depth increases, light attenuates most of the red content and image appears in bluish-green color. These images also have low contrast, color cast and hazy appearance. Existing methods may need specialized hardware or it may be based on multiple images of the same scene. Thus, they cannot be used in real-time or video acquisition task. So, it's better to form an effective method for color enhancement and image restoration of images. Here depth map estimation along with image blurriness is proposed. As light travels deeper into the water, the image gets blurred and this is used to obtain depth map. The backlight is also obtained. These factors are substituted in the IFM (Image Formation Model) to restore the image.

Index Terms- Underwater image restoration, image enhancement, IFM, Image restoration.

I. Introduction

In oceanic engineering, underwater imaging has a significant role. Underwater images have large scope in various research work. Nowadays several technologies are available to record underwater images and videos like waterproof cameras. But underwater images suffer from various demerits in case of visibility, contrast, illumination. This is because light rays on its path from the object to the camera get reflected by the organic particles dispersed in water. The major problem in image restoration is lack of reference image and underwater environment. In underwater, light propagation suffers from absorption and scattering. Scattering is because of collision with suspended particles and causes light rays to reflect in different directions, which can add a hazy layer to the image. Absorption causes energy loss of light rays and it depends upon the water medium properties such as density and turbidity. As turbidity increases absorption rate increases. Colors degrade gradually depending on wavelength as it moves deeper. Red light with large wavelength value attenuates more than shorter wavelength blue color light. Thus, blue and green light reaches depth compared to red and orange. Thus, underwater images have appeared in bluish-green. The methods used to increase the underwater image quality falls under two categories restoration and enhancement. Enhancement involves unsharp masking, histogram equalization, etc. for visually better results. The enhanced image is not necessarily to be exactly similar to the original image. But restoration can improve the image as same as the original image by modeling degradation. It restores an image by estimating underwater image formation model parameters. It can be modeled as a linear combination of the direct component and backscattered component. Direct component is the amount of light reflected from the object surface, only a portion of it reaches the camera and remaining gets scattered or absorbed. Scattering is of two types: forward and backward scattering. Backward scattering is responsible for low contrast thus it is included in the image formation model and the forward scattering component is neglected. Image formation model is given by $I(x) = S(x)\,t(x) + B\,(1-t(x))$ (1) $I(x)$ is observed intensity at pixel x. $J(x)$ is scene radiance, a fraction of light reflected from the scene into the camera. $t(x)$ is a transmission map, a portion of the light that is not scattered or absorbed. B is a backlight, portion of light scattered into the camera by the suspended particles, it may add a hazy layer to the image. The main steps in this paper include image blurriness estimation, backlight estimation, depth map estimation, transmissionmap estimation, and scene radiance recovery. Finally, non-reference image quality assessment methods such as BRISQUE, entropy are used to measure the restored image quality. Autonomous Underwater Vehicle (AUV) is an underwater unmanned vehicle for ocean exploration. It is suitable for detecting unknown environment and has the functions of autonomous decision-making, planning and obstacle avoidance in complex environment. Autonomous localization is of great significance to realize safe and efficient work of AUV. There are two main localization methods of AUV: dead reckoning and acoustic beacon positioning, but their complexity and the expensive instrumentation restrict the promotion of AUV. Compared with inertial navigation and acoustic beacon positioning, SLAM is a method with small-sized and affordable instrument. Simultaneous location and mapping (SLAM) refers to estimating a robot's pose (position and orientation) in unknown environment through repeated observation of environmental characteristics. Based on this foundation, an incremental map of the surrounding environment is constructed. Through the efforts of researchers, the SLAM technology has been widely used in fields such as unmanned aerial vehicle, sweeping robot, unmanned driving and intelligent wearing equipment. Compared with the SLAM of land and aerial unmanned system, the application of the SLAM in AUV positioning and navigation is just beginning. The research on AUV SLAM was mainly based on extended Kalman Filter and Particle Filter. Sonar is used as environment sensing sensor [1-2]. The earth is associate aquatic planet and the maximum amount as eightieth of its surface is roofed by water. Moreover, there is a strong interest in knowing what lies in underwater. Present days, an image of deep waters has a scope to large investigation to explore the underwater for sea floor expedition and navigation. Enthusiasm of underwater imaging includes the inspection of plants, seabed exploration, the search for wrecks up and to the exploration of natural resources. There were several issues faced by the human in the underwater, if he dives deep into the ocean and stay there for a long time to perform experimentation. [1]. Due to the above reasons, unmanned remote vehicles are used to sea floor exploration

II. Existing Work or Literature Survey

Underwater image quality improvement approaches present a path to magnify the object recognition in underwater surrounding. A heap of research started for the up gradation of imagevisual quality, but a little amount of work has been carried out in this area. In the deep waters, image quality is degrading due to poor illumination conditions and the light properties differ in water compared to air.[2]. There were several parameters which decreases the quality of an image in underground waters. So, in order to remove all these effects there are several techniques has been implemented and practiced. B. Need for Preprocess Initially processing is necessary for deep water images due to their poor-quality during acquisition. Necessity for pre-processing of deep-water images [1] is discussed below: (i) Quality of images taken from deep water is deteriorated due to light ray attributes like scattering and absorption of light. (ii) Specificity of surroundings such as lighting inequalities, water torridness, and blue complexion is more or less influential when vehicles move. (iii) Video or image captured from deep waters like unknown rigid scene, and the depth of the scene and low light sensitivity due to Marine snow etc.

Traditional Techniques For Image Enhancement: There are several techniques which are used very frequently for processing the image to improve the visual quality. Some of them are as follows: (i) Contrast Stretching (ii) Adaptive Histogram Equalization 2.1.1 Contrast stretching The contrast stretching is a method to transform high intense region of image into brighter and less intense region into darker by using a predefined transformation function T(r) [2]. Generally, the underwater images will have fewer grey values. There are 256 grey values. ‘0’ indicates black and ‘255’ indicates white. In this method the current grey value of the image is stretched towards 255 i.e., from black to white, pixel by pixel. That means the contrast of the image is stretched, so that the quality of the image is improved for better vision.

Adaptive histogram equalization: Adaptive histogram equalization is a PC based image processing technique which is used to improve the quality of image properties like contrast. It is similar to contrast stretching method but with a slight difference. It computes several intensities of specific gray value, each corresponding to a distinct portion of an image, and with the help of them intensities are rearranged by applying a suitable transformation function. For example, a simple transformation function such as each pixel transformed based on the histogram of a square surrounding the pixel [3]. Existing values will be mapped to new values keeping actual number of intensities in the resulting image equal or less than the original number of intensities. The transformation function applied on the histogram is proportional to the cumulative distributive function (CDF) of pixel values in the neighborhood. Therefore, it suits for enhancing the local details and enhancing the edge information of each region of an image.Histogram equalization is a technique for changing the overall pixel intensities based on transformation function and contrast of an image. Histogram equalization is an effective technique which will benefit for the images with extreme contrast values. The limitation of this technique highlights the unwanted noise present in the background of an image and lead to loss in the information signal. It results in undesired effects in the resultant images [4].

IMAGE: An image is a two-dimensional picture, which has a similar appearance to some subject usually a physical object or a person. Image is a two-dimensional, such as a photograph, screen display, and as well as a three-dimensional, such as a statue. They may be captured by optical devices—such as cameras, mirrors, lenses, telescopes, microscopes, etc. and natural objects and phenomena, such as the human eye or water surfaces. The word image is also used in the broader sense of any two-dimensional figure such as a map, a graph, a pie chart, or an abstract painting. In this wider sense, images can also be rendered manually, such as by drawing, painting, carving, rendered automatically by printing or computer graphics technology, or developed by a combination of methods, especially in a pseudo-photograph.

IMAGE FILE SIZES: Image file size is expressed as the number of bytes that increases with the number of pixels composing an image, and the color depth of the pixels. The greater the number of rows and columns, the greater the image resolution, and the larger the file. Also, each pixel of an image increases in size when its color depth increases, an 8-bit pixel (1 byte) stores 256 colors, a 24-bit

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pixel (3 bytes) stores 16 million colors, the latter known as true color. Image compression uses algorithms to decrease the size of a file. High resolution cameras produce large image files, ranging from hundreds of kilobytes to megabytes, per the camera's resolution and the image-storage format capacity. High resolution digital cameras record 12-megapixel (1MP = 1,000,000 pixels / 1 million) images, or more, in true color. For example, an image recorded by a 12 MP camera; since each pixel uses 3 bytes to record true color, the uncompressed image would occupy 36,000,000 bytes of memory, a great amount of digital storage for one image, given that cameras must record and store many images to be practical. Faced with large file sizes, both within the camera and a storage disc, image file formats were developed to store such large images.

Image file formats are standardized means of organizing and storing images. This entry is about digital image formats used to store photographic and other images. Image files are composed of either pixel or vector (geometric) data that are rasterized to pixels when displayed (with few exceptions) in a vector graphic display. Including proprietary types, there are hundreds of image file types. The PNG, JPEG, and GIF formats are most often used to display images on the Internet.

Image fundamental Image Acquisition: is to acquire a digital image. To do so requires an image sensor and the capability to digitize the signal produced by the sensor. The sensor could be monochrome or color TV camera that produces an entire image of the problem domain every 1/30 sec. the image sensor could also be line scan camera that produces a single image line at a time. In this case, the objects motion past the line.

Image enhancement: is among the simplest and most appealing areas of digital image processing. Basically, the idea behind enhancement techniques is to bring out detail that is obscured, or simply to highlight certain features of interesting an image. A familiar example of enhancement is when we increase the contrast of an image because “it looks better.” It is important to keep in mind that enhancement is a very subjective area of image processing.

Image restoration: is an area that also deals with improving the appearance of an image. However, unlike enhancement, which is subjective, image restoration is objective, in the sense that restoration techniques tend to be based on mathematical or probabilistic models of image degradation.

Color image processing: The use of color in image processing is motivated by two principal factors. First, color is a powerful descriptor that often simplifies object identification and extraction from a scene. Second, humans can discern thousands of color shades and intensities, compared to about only two dozen shades of gray. This second factor is particularly important in manual image analysis.

Wavelets and multi resolution processing: Wavelets are the formation for representing images in various degrees of resolution. Although the Fourier transform has been the mainstay of transform-based image processing since the late1950’s, a more recent transformation, called the wavelet transform, and is now making it even easier to compress, transmit, and analyze many images. Unlike the Fourier transform, whose basis functions are sinusoids, wavelet transforms are based on small values, called Wavelets, of varying frequency and limited duration.

Compression: As the name implies, deals with techniques for reducing the storage required saving an image, or the bandwidth required for transmitting it. Although storage technology has improved significantly over the past decade, the same cannot be said for transmission capacity. This is true particularly in uses of the Internet, which are characterized by significant pictorial content. Image compression is familiar 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. Morphological processing: Deals with tools for extracting image components that are useful in the representation and description of shape. The language of mathematical morphology is set theory. As such, morphology offers a unified and powerful approach to numerous image processing problems. Sets in mathematical morphology represent objects in an image. For example, the set of all black pixels in a binary image is a complete morphological description of the image.

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.

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III. WRITE DOWN YOUR STUDIES AND FINDINGS

Underwater image restoration using depth map estimation. Image blurriness is used as a before acquiring a depth map. As depth increases, image blurriness also gets increased. Here backlight is retrieved from the largest blurriness region and lowest variance region. A backlight is estimated from the top brightest pixel. If artificial lighting is used for illumination, foreground objects appear to be brighter than background objects. So, selecting the brightest pixels may lead to erroneous results. Then substituting backlight and depth map in IFM scene radiance is restored. Fig.1 shows the block diagram of the proposed method.

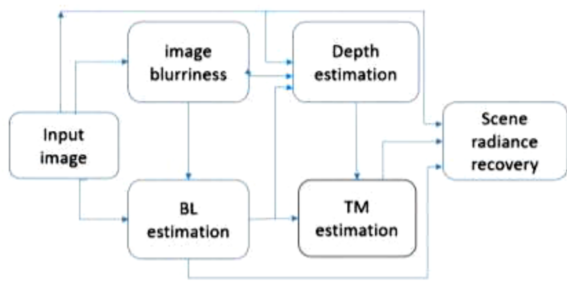
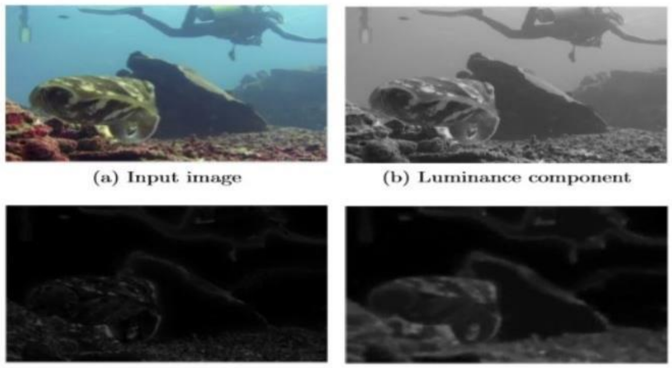


Image Blurriness Estimation: Image blurriness is due to scattering by suspended particles, minerals, rocks in the water. There is a linear relationship between blurriness and depth. Thus estimating blurriness in the image gives depth information. There are 5 types of image blurriness measuring techniques. In the first category, image blurriness is found by measuring the energy of the image. Blurring can smooth edges of the image and thus decreases high-frequency coefficients energy, thus a comparison of the energy of original and degraded image gives blurriness metric. The second category considers the edge of the image since blurriness may convert the sharp edges in the image into a smooth one. The edges and its width are obtained from vertical/horizontal gradients. The third category involves pixel intensity distribution. This method considers, a sharper image has a greater value of entropy and variance. The fourth category blurriness evaluation includes local gradient measures. Singular value decomposition is a local gradient measure used for blurriness estimation. The fifth category uses a combination of the other 4 categories. But these methods are susceptible to noise since noise may increase high-frequency content in an image. In underwater image restoration, a reference image is not available thus above mentionedmethods for blurriness calculation cannot be used. First, the input image is converted into YCbCr color space Y represents luminance and Cb, Cr represents chrominance values. Blurriness is calculated using the luminance component only, rather than considering chrominance values. Since it is perceptually more representative, it easy to tell blurry and sharp areas based on Y. Sharp edges in the image indicate blurriness is less. Then calculates the difference between the luminance component and Gaussian filtered version of that component. Gaussian filtering is a lowpass filter it removes high-frequency content such as edges or noise and retains low frequency information. This difference contains sharp objects and fine details. Then a maximum filter is applied to this difference. This filter calculates the maximum value within the window and this window is slid over. A window size of 7 to 31 is suitable for any image size. Here window size equal to 7 is used. The output image is reconstructed by hole filling. The output image contains only sharp details and the blurred regions are removed. Thus in the blurriness map, small value means the corresponding pixels in the image are blurry, large value means they are not blurry. So sharp edges would have large values and a smooth region would have small values. However, a smooth region encompassed by sharp edges would be considered not blurry since they all belong to a single object. Fig.2 shows the image blurriness



(a) Input image (b) Luminance component

(c) Rough map (d) Blurriness map

Backlight Estimation: The backlight is due to the scattering of light by the particles in water. It adds a hazy layer and reduces image contrast. To overcome the drawbacks of backlight estimation methods (in the case of artificial lighting or brighter foreground object) this method considers variance and blurriness in addition to 1 percentage of top brightest pixels. Here largest blurriness and lowest variance regions are considered, these regions are obtained using quadtree subdivision. In low variance region pixel values do not change dramatically. Thus it is more likely to find backlight. Blur regions always have low variance but low variancedoes not always infer a region is blurry. Thus low variance and largest blurriness criteria are not interchangeable. The backlight has a dependence on depth because the scattering of ambient light increases as goes deeper into water. To take this dependence, backlight estimation considers the largest blurriness region.

The image is first divided into four quadrants equally according to blurriness or variance. Then the quadrant with the lowest variance (in the case of blurriness region with the largest value) is chosen. Variance within a quadrant is obtained by the averaging variance of individual pixels. The quadrant with the lowest variance is further divided into four. This process is repeated until the quadrant size got lesser than a predefined threshold. The threshold value must lie between 0 and 1. From the largest blurriness region, lowest variance region, and top brightest pixels, the maximum, and minimum of the backlight are obtained. It is not able to find backlight anywhere in the image so maximum and minimum values are separately obtained for each color channel. Then calculates the ratio of pixels with intensity greater than a threshold (here chosen 0.5) to the total number of pixel values. If the image is taken under sufficient lighting this ratio would have larger value otherwise it would be a smaller value. When the percentage of bright pixels is high then the estimated backlight is bright is more suitable thus the maximum value of backlight is chosen as estimated backlight. If the image is taken without sufficient lighting (smaller ratio) then the minimum value of backlight is chosen as estimated backlight. In between these extreme conditions, the backlight is calculated as the combination of these maximum and minimum values. The figure shows backlight estimation where the blue line indicates variance and the red line indicates blurriness. The white portion indicates the lowest variance and largest blurriness region.

When the image $I^c(y)$ is captured at a larger depth the red channel information is almost lost. Red channel content is, $R(x) = \max_{y \varepsilon \omega(x)} I^c(y)$ (2) where $\omega(x)$ is a window of size 7,centered about x and $c\ \varepsilon \{r,g,b\}$. Then depth map is, $d_R = 1-K(R)$ (3) Since three different depth maps are combined, for them to be in the same range [0, 1] stretching function K is used. It is given by $K(L) = L-L_{min} / L_{max} - L_{min}$(4) 2)Using 3color channel: Difference between attenuation of different color channels (red, green, blue) can be used as a prior to calculate depth map since light undergoes attenuation which depends on color. Red light has a larger attenuation constant than green and blue light. For this depth estimation method, the difference between the maximum value of green and blue channels and that of the red channel is calculated. When the difference is larger it indicates that red channel intensity is low, the image is distorted badly and depth value is high. If this blue-green channel has a smaller value the red channel is less attenuated and depth is low. The prior value is, $BGR = \max_{y \varepsilon \omega(x), c \varepsilon (g,b)} I^c(y) - \max_{y \varepsilon \omega(x), c \varepsilon r} I^c(y)$ (5) When the prior value increases depth also increases. Then the depth map is: $d_{BGR} = K(BGR)$ (6) (3) Using image blurriness: As the image is more blurred, indicates that the image is from more depth and vice-versa. If image blurriness value is small, it's blurry and large value indicates the image is sharp. Thus, the depth map is; $d_B = 1 - K(\text{Blurriness map})$ (7) When there is insufficient lighting, method of using red channel content is used. If there is an intense backlight, red content in the image is retained and this method is failed. In this case, the second method using 3 color channels is proposed.

Transmission Map Estimation: Transmission map is the part of the light that is not scattered or absorbed and finally reaches the camera. According to Beer-Lambert law light is exponentially attenuated with distance when it travels through a medium. $t^c(x) =$

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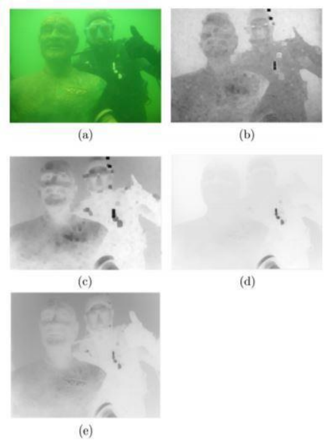
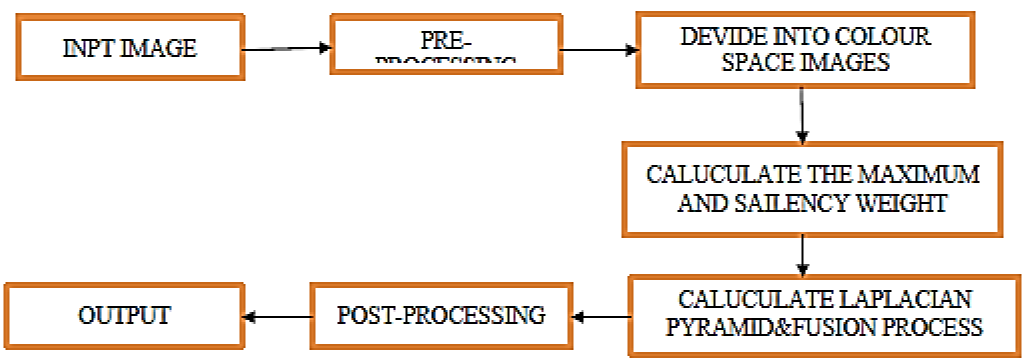
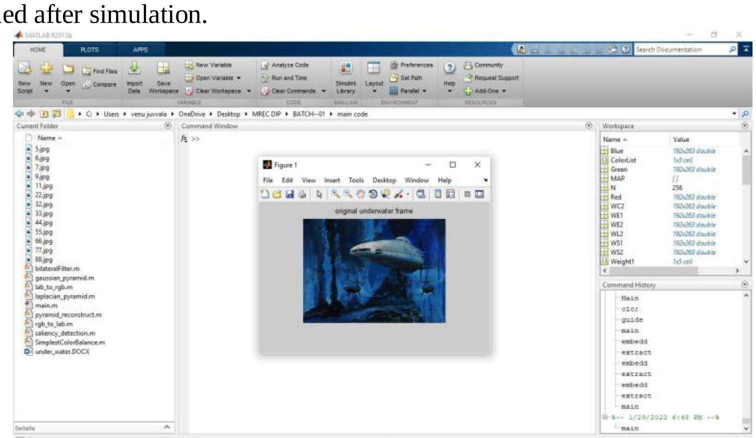
exp(−βc d(x)) (8) where d(x) is scene depth and β is attenuation coefficient c represent RGB color channels. Transmission map is separately obtained for each color channel. Underwater image restoration using a single image makes use of the assumption that attenuation is wavelength independent (or color independent). But in underwater red light decays faster than green light and blue light. In this method wavelength-dependent attenuation is considered. The standard wavelength of red, green and blue are 620 nm, 540 nm, 450 nm respectively. Attenuation constant is proportional to wavelength and inversely proportional to the backlight. Using this relation the attenuation coefficient is:



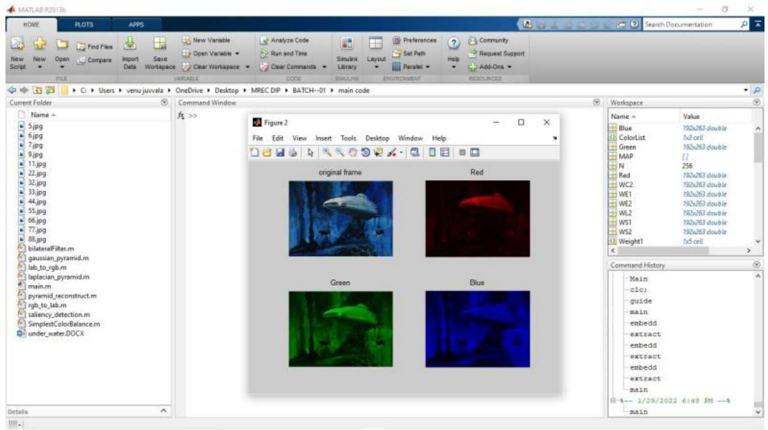


IV. Results and discussion

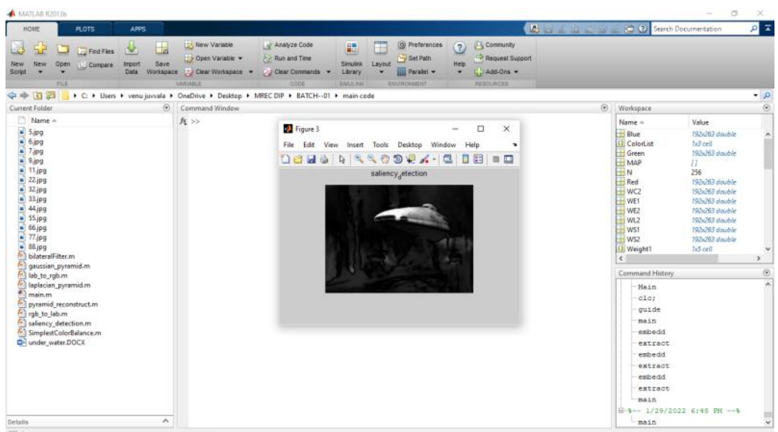
Following are the results obtained after simulation.



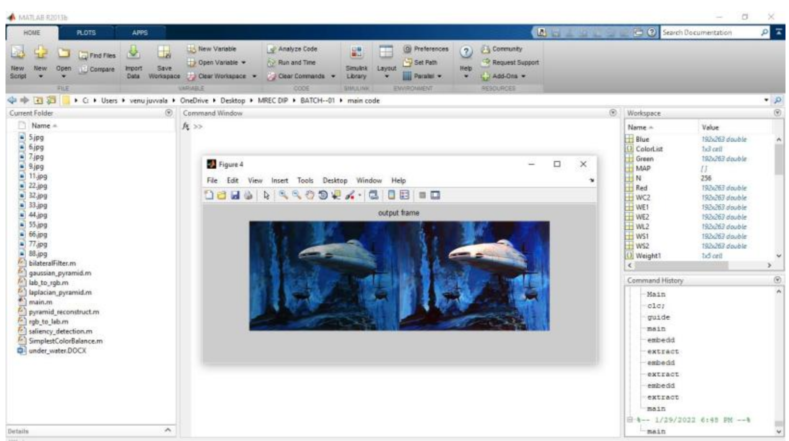
Input image



Colour separation



Saliency detection



Output image

V. CONCLUSION

Underwater image restoration is a difficult task as there is a shortage of reference images and a changing underwater environment.

Existing methods need specialized hardware or multiple images of the same scene, and is inadequate for realtime and video applications. Algorithms using a single image also deals with several problems due to the wavelength dependency of light and its attenuation. Here images are restored using depth estimation based on image blurriness and light absorption. Image blurriness is linearly dependent on depth. Thus image blurriness is obtained to provide a measure of a depth map. This technique utilizes the largest blurrinessand lowest variance region to estimate backlight and thus avoids faults of bright foreground objects. Finally, the image is restored by providing estimated parameters in the image formation model. It requires only a single image of a scene. Quality of restored images is evaluated using non-reference image quality measures and works well with many underwater images without numerous images dataset of one scene itself. Therefore, this technique provides better restoration results compared to other existing methods.

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