Image Processing Project

CSE 468

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Abstract

In this report, we discuss proposed solutions to the tasks required by the International Competition for Autonomous Underwater Vehicles. The tasks mainly ask for observation and identification of different colored objects under water. Also, a disparity map is generated to aid the AUV in its environment identification and distances between the AUV and surrounding obstacles in a process of depth estimation. Image processing tasks include a step of preprocessing to the input video to improve white balance and enhance colors. Then a step color identification is made followed by contour detection algorithms to know the shape of the colored object. A marker is added to the video frames to show the position of the identified object as well as its color based on the color of the marker. The final step is to generate an output video of the resulting images to rebuild the input video with the identification markers. This image processing algorithm is generalized in multiple tasks to perform for both rounded objects (Buoys) with red, green, and yellow colors as well as rectangular objects (Gates) with orange color. The AUV has a localization module that is based on feature detection and depth estimation. Depth estimation is the process of estimating how far objects are relative to the camera frame in real life. One way to achieve depth estimation is Stereo vision. By having an input of both camera images, we can generate a disparity map to identify object depth in the frame. We also added a smoothing filter to remove noise and make the disparity map clearer.

Overview

Degradation of underwater images is different from normal images. In underwater imaging light interacts with water in two ways, scattering and absorption. The scattering and absorption together is called attenuation of light in water. This attenuation is wavelength dependent. Because of scattering and absorption, underwater images are affected by back scattering, forward scattering and absorption of light in water. As a result of which the images are degraded, and also dominated by green or blue color. Water is not only a source of degradation, but underwater images are also affected by suspended particles and dissolved compounds in water. The degradation also depends upon depth of water, day time, geographical location, source of light and physical properties of water etc. Many underwater applications need clear underwater images. Clear underwater images can be achieved by image enhancement and restoration techniques. Underwater image enhancement techniques include contrast enhancement, non uniform illumination correction, and color correction techniques.

The algorithm used in this project to enhance the color of the underwater videos is white balance algorithm.

In order to classify underwater objects based on its color “ Red Buoy, Green Buoy, Yellow Buoy, Orange Gate legs” we need to color segmentation algorithm, It may be the era of deep learning and big data, where complex algorithms analyze images by being shown millions of them, but color spaces are still surprisingly useful for image analysis.

Computer stereo vision is the extraction of 3D information from digital images. By comparing information about a scene from two vantage points, 3D information can be extracted by examining the relative positions of objects in the two panels. This is similar to the biological process Stereopsis.

Image Enhancement

Development of autonomous underwater vehicles, advancement in underwater infrastructure and curiosity about underwater world has increased research opportunities in underwater image and video processing. Image of anyobject is created by reflection of incident light (artificial light or sunlight) from the object. In case of underwater imaging the light interacts with water when it is travelled from source to object and back to the camera. This causes degradation of image. As water is 800 times denser than air, the degradation problem of underwater images is different from normal images. Underwater image degradation is caused by three phenomena, absorption, back scattering and small angle forward scattering of incident and/or reflected light.The first problem is absorption of light, which is wavelength dependent. Red is attenuated most and blue least. As light travels deeper and deeper the colors are dropped off. First the red color is diminished, then orange, yellow and so on but the blue color travels longest. So the underwater images are dominated by blue color.Second problem encountered is backscattering. In this scattering the light is reflected back without reaching the object. This scattering is caused by reflection of light in backward direction by particles in water and water itself. As this reflected light is in the field view of the camera without reaching the object, it does not contribute to the image and degrade the image contrast. Third problem is small angle forward scattering. This is forward scattering of incident and/or reflected light by small angles. All the above three components are function of distance of the object from camera, depth of the object and characteristics of water.

An easy way to solve some of these problems is white balance algorithm. When a white object is illuminated under a low color temperature, it will appear reddish in the recorded image. Similarly, it will appear bluish under a high color temperature. The goal of white balance is to process the image such that it looks as if it is taken under canonical light. Generally, white balance algorithms consist of two steps. They first estimate the illumination, and then use the result obtained to compensate for the image. To maintain the color constancy of an image taken under different light sources, computational color constancy algorithms have been applied to accomplish white balance for underwater images.

the fig 1.1 shows an underwater image with its color histogram before applying the white balance algorithm, which is show the absence of the red color, and in fig 1.2 the same image after applying the white balance algorithm and its histogram, which is shows the balance in all colors and more clear image

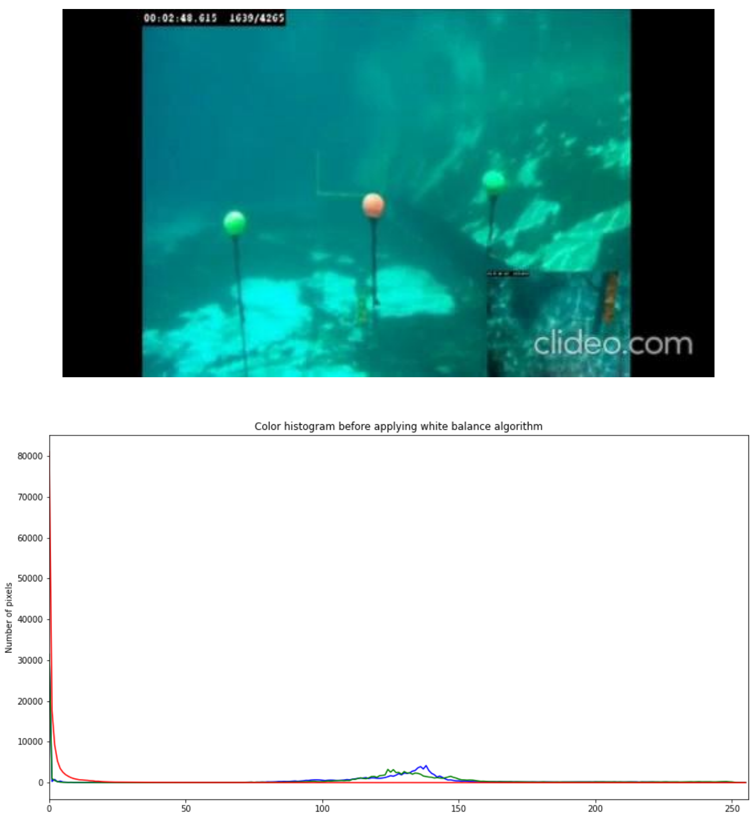

Fig 1.1

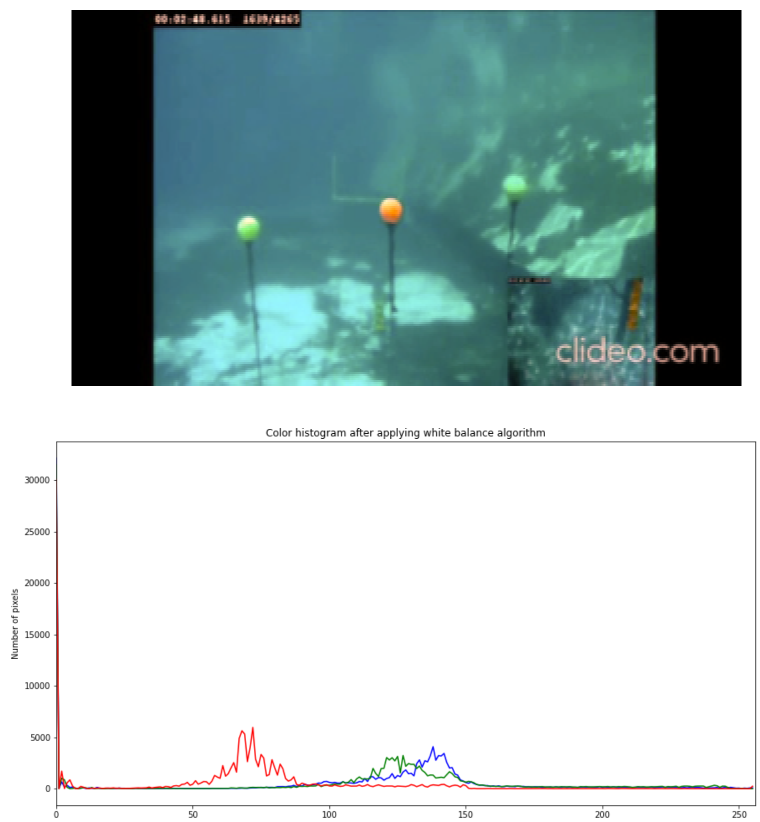

Fig 1.2

Color Segmentation

In the most common color space, RGB (Red Green Blue), colors are represented in terms of their red, green, and blue components. In more technical terms, RGB describes a color as a tuple of three components. Each component can take a value between 0 and 255, where the tuple (0, 0, 0) represents black and (255, 255, 255) represents white.

RGB is considered an “additive” color space, and colors can be imagined as being produced from shining quantities of red, blue, and green light onto a black background, RGB is one of the five major color space models, each of which has many offshoots. There are so many color spaces because different color spaces are useful for different purposes.

HSV and HSL are descriptions of hue, saturation, and brightness/luminance, which are particularly useful for identifying contrast in images, HSV is a good choice of color space for segmenting by color, as mentioned briefly above, HSV stands for Hue, Saturation, and Value (or brightness), and is a cylindrical color space. The colors, or hues, are modeled as an angular dimension rotating around a central, vertical axis, which represents the value channel. Values go from dark (0 at the bottom) to light at the top. The third axis, saturation, defines the shades of hue from least saturated, at the vertical axis, to most saturated furthest away from the center, fig 2.1 .

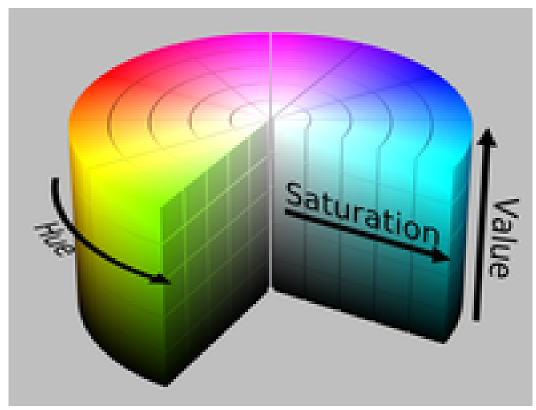

Fig 2.1

In HSV space, the colors are much more localized and visually separable. The saturation and value of the colors do vary, but they are mostly located within a small range along the hue axis. This is the key point that can be leveraged for segmentation.

By selecting a range for the color and creating a mask from this range, then imposing the mask on top of the original image, which keeps every pixel in the given image if the corresponding value in the mask is 1.

Then by applying some morphological operation to enhance the image and reduce any noise using circular structure element for the rounded shape objects "Buoys" and squire structure element for the rectangular shape objects "Gate Legs", we can extracting the Contours of the resulting image and draw around it as shows in fig 2.2 & 2.3.

Fig 2.2, Detected Buoys "red, yellow and green

Fig 2.3, Detected Gate Legs "Orange"

Stereo vision

In traditional stereo vision, two cameras, displaced horizontally from one another are used to obtain two differing views on a scene, in a manner similar to human binocular vision. By comparing these two images, the relative depth information can be obtained in the form of a disparity map, which encodes the difference in horizontal coordinates of corresponding image points. The values in this disparity map are inversely proportional to the scene depth at the corresponding pixel location.

Disparity map refers to the apparent pixel difference or motion between a pair of stereo images. To experience this, try closing one of your eyes and then rapidly close it while opening the other. Objects that are close to you will appear to jump a significant distance while objects further away will move very little. That motion is the disparity.

In a pair of images derived from stereo cameras, you can measure the apparent motion in pixels for every point and make an intensity image out of the measurements fig 3.1 .

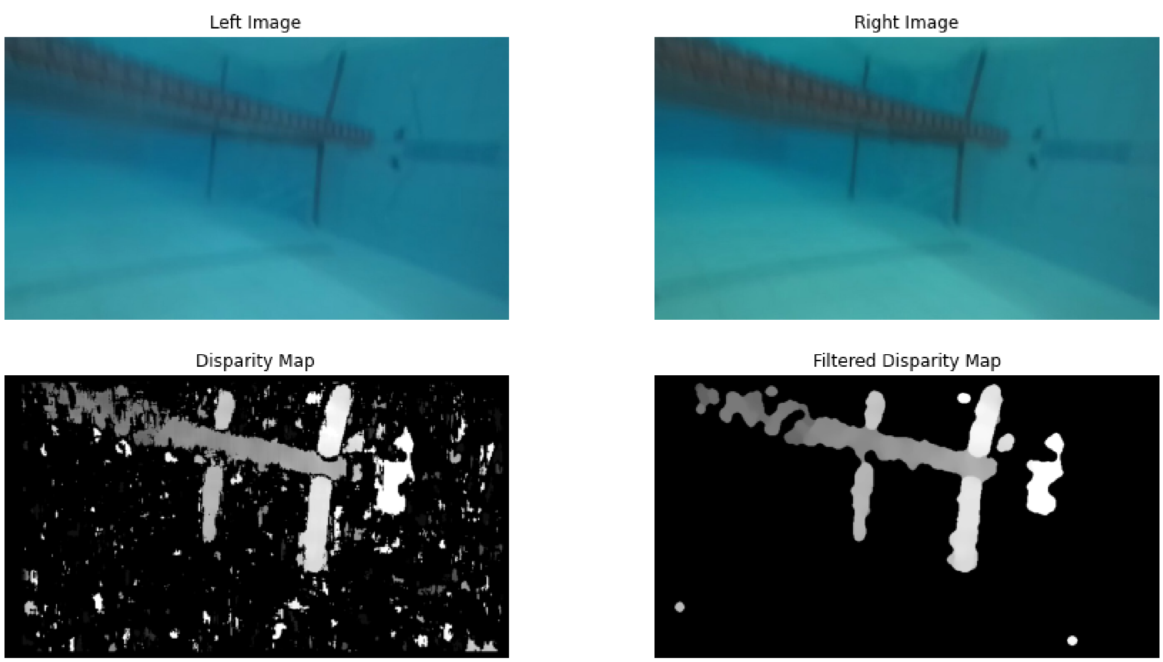

Fig 3.1

Conclusion

All in all, we tested the proposed solution of image processing and enhancement to verify its effectiveness in the underwater environment. Each taken step is vital for the completion and the resulting output. The AUV can now be equipped with a reliable image processing system that aids in identifying and observing different colors and objects as well as prominent stereo vision analysis to get filtered disparity maps.

Most if not all the used image processing algorithms are considered basic processes such as median filtering and morphological operations. This proves that the integration of ordinary ideas can turn out to be an extraordinary feat.

While working on this project, we learned multiple ideas concerned about image preprocessing. This step is usually overlooked in courses as it is considered a prerequisite to start any image processing. Making sure that the image dimensions are compatible with used functions as well as the color configuration was important to successfully use the OpenCV libraries. We also learned about white balancing and how to clarify images that can be considered unusable without the image preprocessing. A new encounter was that of converting the video clip into multiple frames to enable image processing then linking it all back together to form the modified video footage.

In the end, this project showed a viable solution for underwater AUVs, but it can still be improved to eliminate any false positive markers. This can be done by meticulously tuning the thresholds that differentiate between colors and shapes. Another future improvement might be in the optimization process of the code to enable general case usability in real time operation.

Appendix

Resulting Videos and Images