



# Underwater Image Restoration And Enhancement Through Convolutional Neural Networks

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## Abstract

In the modern world underwater images have become a very important aspect of various different fields and industries. Due to this, the requirement of high-quality underwater images has become very important in recent times. These images can be used for environmental monitoring, biodiversity, documentation, ocean exploration, as well as pollution awareness. Although all of these require high-quality underwater images it has become a constant challenge in order to obtain them. This is due to the fact that underwater images tend to have various problems that they face which degrades the quality of the image itself. Some of the issues that are faced when dealing with underwater images are color distortion, low contrast and blurriness, uneven illumination, and noise from the various particulate matter that is present in the water. All these issues sort the image to make it unusable in all the fields that we previously talked about. This is why we would like to use convolutional neural networks in order to create a model that is able to enhance these images to increase the quality. In this study, we would like to address the various issues that underwater images face, and how we intend on solving them. To do this, we will have to use various data sets in order to train the model, which we will create in order for image enhancement, and then vigorously test it using various different parameters, which we will also explain in our report. Through the study, we aim to create a model, which is able to take any form of underwater image and accurately enhance it so that it can be used in the many fields that are required today., which we will also explain in our report. Through the study, we aim to create a model, which is able to take any form of underwater image and accurately enhance it so that it can be used in the many fields that require it today.

## 1 Introduction

As we continue to explore the world that we currently live in, we are now at the stage where we are exploring underwater. There is currently so much region under the water that we have not yet explored or even discovered due to its sheer depth and inaccessibility to us. Over the years, we have created many different machines to go underwater and explore for us. However, many of them have not been able to get the job done. When we try to explore in great depth one of the major issues that we face as human beings is the high amounts of pressure as well as the issues our body takes as it is exposed to them. Even with a large oxygen tank and the ability for submersible drivers to go that deep into the ocean they often tend to take great risks with their own life due to the various issues they face such as oxygen poisoning and getting habituated to the atmospheric pressure at those depths. This is why we have decided to use

different machines such as underwater drones, or robots to scour these underwater surfaces to collect the data and resources that way may require. However, when we look into this approach, one of the major issues is the fact that we are unable to properly see the ocean floors or any images taken in the ocean due to the various distortions that take place within the water.

Images are taken by capturing the light and mapping that on the sensor but the camera has however a great debt light is often lacking due to which we get very dark images or even very blurry images that are simply unusable even with a large light source in place. When we look into the major issues, we face on capturing underwater images there are five major problems that we can dive deeper into and discuss. The first issue that we will encounter when dealing with taking images under the water is the way that light is absorbed and scattered at various depths within the ocean. This is caused by the fact that water is able to absorb light at a very high rate due to which it is not able to properly go into deep parts of the ocean. On top of this even if one light is being absorbed it is not always a single fraction of the light that is constantly absorbed as the red-light tension disappears faster within the first few meters of entering the ocean. The second most affected fragment is the blue and green light which tend to be dominating deeper into the water. Although the fact that light itself is absorbed is one of the major issues, another phenomenon we face within the ocean is the scattering of the light itself due to all of the particles that exist within the water. When we take these issues into account, they impact the image by drastically, reducing the color, vibrancy and sharpness of the images themselves. Due to this, we will have to spend a large amount of time processing the images in order to destroy these details so that they can be usable. The second major issue that we face when taking pictures underwater is limited visibility due to turbidity. Not only do all the particles such as sand, algae, and pollutants scatter the light, but they also reduce the visibility and make it much harder for us to see further into the ocean. Due to this issue, it is often very difficult to capture clear images in water that is murky or even shallow due to the very poor visibility. The third issue is color distortion due to the fact that different wavelengths of light are absorbed in different manners in water. As we have discussed before, red and orange are the first colors to dissipate and be absorbed by the water which causes the blue and green light to completely dominate the images that we capture. This causes the colors to be very inaccurate which can cause major issues when we look into marine observations or documenting various objects leading to wrong scientific observations causing issues down the line. The fourth major issue that we face is motion disturbance when we take images deep in the ocean. Due to the constant movement of water and the various particles that it may contain, they tend to move across the image, making it very hard to capture stable images. Furthermore, when we are working with aquatic life in these depths it becomes even more difficult if they move quickly which causes us to get very blurry images of them. Taking this to your account, we can look into our fifth major issue, which is the high levels of noise better capturing the image requirement of a high ISO at these depths. These are all a few of the most major problems that we encounter when capturing images underwater. Due to these reasons many industries struggle with capturing high-quality underwater images and often tend to look for solutions in order to solve them.

Some of the industries that rely on this are marine, biology, oil & gas industries, fisheries, and even oceanography. These are only a few of the industries that require underwater images, and they are far more; however, they all depend on these images in order to process the various things that happen in the water. For example, in marine biology, they need high-quality images to ensure that they are able to track the biodiversity and constantly monitor the health of various habitats in order to ensure that they are safe. It is very important that they get images of high resolution due to the fact that they will have to constantly catalog and document all of their findings to pass down to the future. In industries that deal with boiler gas they have to constantly ensure that they monitor the entire rig to prevent any cracks or corrosion that may take place on the structure. They must also use underwater images when they are surveying various sites in order to build new structures in the future. Fisheries was one of the other

industries that we mentioned with the requirements of underwater images in order to inspect their fish farms to ensure that there is not a spread of any particular disease or even an issue of overpopulation. Overall, these are only a few of the use cases in the various industries that exist in the world today. However, there are many other use cases for high underwater images which we have not discussed, but still exist in the world. This is why we have made it our goal in order to create an effective machine learning model that is able to effectively take any form of underwater image and enhance it to meet the standards. In our project, we have decided to train a convolutional neural network in order to take these normal images and enhance them to optimal conditions. In our project we are able to work with this convolutional network model and tweak it in many different ways to overcome the many issues that we previously discussed. In the later sections of our paper, we would like to thoroughly explain how we were able to build this model and further look into the various steps we took in its creation. Before we started working on our model, we began by looking into various other methods that currently exist in the world for image clarification. We would like to take a look into these existing methods to identify their benefits and disadvantages so that we can keep them in mind when we work on our own convolutional neural network model. In the following section, we would like to discuss our findings and the research that we conducted on the existing methods.

## 2 Related Works

Next, we were able to look into various other methods that were used when it came to the announcement of underwater images. The methods used ranged from histogram equalization, wavelet-based methods, retinex based methods, dehazing techniques, image fusion methods, and various different machine learning models. All of these approaches were able to accurately ensure that the image was enhanced and, in a form of usable condition. Through these many methods that we looked into the most effective, one was the deep learning models which were created for the enhancement of images. This was due to the fact that they were able to handle the complex image features far better than the other methods. This caused them to be able to accurately depict all of the objects in the image, and ensure that they were taken into account when enhancement was taking place. The only drawback of this approach was the fact that it required substantial computation resources and it often struggled when there was a scarcity in the amount of data that we had. Based on how the model itself was created, many of the models that we looked into had a very serious issue with overfitting during the training stages, which caused the overall model to have very low accuracy. To overcome this many people have decided to take a hybrid approach which combines multiple different techniques, such as machine learning with existing physical models, and this was seen as the second-best option. Through this approach, they were able to combine the strengths of these various different methods and models so that they are able to improve on the quality of the images that we enhanced. We were also able to observe that these hybrid models were able to do far better when we are dealing with multiple underwater conditions, and this approach itself was able to solve all of them irrespective of their condition. The least effective method that we looked into were dehazing techniques as well as histogram equalization. These are old methods and were the first methods created in order to solve the issue of underwater images. However, as we have studied, these have been far surpassed by existing methods due to their lack of being able to work well in specific environments. The major issues that they face is a fact that they are unable to efficiently map out to the various objects in the image in order to properly enhance them. This leads to images that tend to over enhance certain areas, causing a lot of noise amplification within these regions. Furthermore, they also failed to address the color distortion in the underwater images, which makes the image clear, however, not color accurate. When we look into the dehazing techniques many of the techniques that exist today are based on terrestrial haze, and when you carry them over to water, they do not work in the same manner. Due to this oftentimes the images that are enhanced are high-quality, however not accurate to the true visual. Overall, the major limitations we observed throughout the various studies we looked into, was mostly just color distortion due to the fact that many of these methods were unable to fully restore the natural colors of the image.

They were also having a hard time dealing with the various particles in the water and the noise that they created, which led to over enhancement in the images themselves. While the most effective methods were deep learning in machine learning methods, these had a very major requirement of competition resources which could increase competition costs exponentially. Taking all of this into account we had gone into the next stage of our project, where we began creating our machine learning model.

### 3 Methodology

For the creation of a machine learning model, we have decided to go with the convolutional neural network as the main method. To create these machine learning models, we had to go over a total of four different stages in its construction. The first stage of constructing the model consisted of pre-processing the data in order to ensure that it could be fit into the model itself. In the second stage, we had to ensure that the architecture of the model itself was properly designed in order to ensure that all of the proper features were extracted and mapped into the model itself in order to make enhancements. Once this was complete, we then had to go into the third stage where we had to train and optimize a model to ensure that the enhancement of the images was proper. The final stage of the project dealt with evaluating and testing the model, using various different performance metrics to ensure that the enhanced image maintained all the qualities of the image that was put into the model itself. Let us now type deeper into these four stages so that we can get a deeper understanding of how the model itself was created. To ensure a comprehensive evaluation of our model's performance, we calculated key image quality metrics, including PSNR, SSIM, and UIQM. PSNR assesses the level of noise reduction, SSIM evaluates the perceptual similarity between the enhanced and original images, and UIQM quantifies underwater image quality based on colorfulness, sharpness, and contrast. These metrics provide a holistic understanding of the model's enhancement capabilities under varying conditions.

#### 3.1 Data Pre-Processing

The preparation of data is one of the most important stages in the creation of any model. This is due to the fact that we must ensure that all of the data that we are using must be in the proper format to be fit into the model so that we can study and train from it. When we were dealing with our data set, the first step was to ensure that we were able to perform the proper augmentation methods on the data by rotating, flipping and scaling them to ensure that they were all in the right orientation and format for our model to study. Once this was completed, we had to ensure that we normalized all of the pixel values and resized all the images to ensure that they were all of the same size and also so that our convolutional neural network was able to process them. Once all this had been completed, we then had to split our data into the training set and testing set. The training set would be used to train our machine learning model, and then the testing set would be used in order to evaluate it so that we can ensure that the model was tested with images that it had no access to. Once this had been completed, we were unable to move onto the next stage of our project.

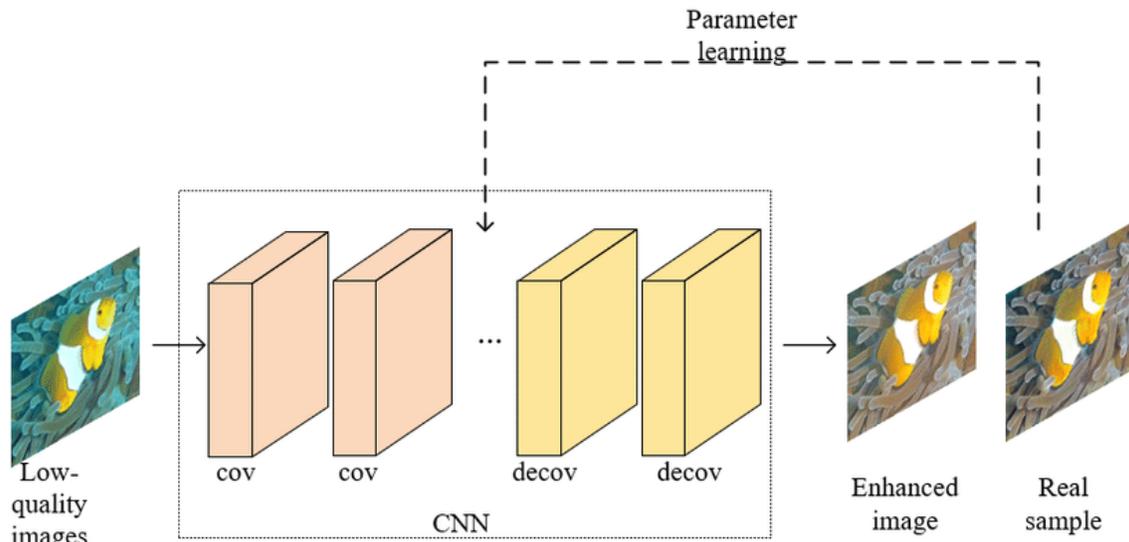
#### 3.2 Model Architecture Design

Now that all the data had been in the proper format, we were not able to go onto the creation of the architecture of our convolutional network. The normal network itself consisted of various parts and layers, which we had to effectively design to ensure that the images were properly analyzed. The first layer we had to work on was the convolutional layer, which is important for the extraction of features using various different filters and kernels. Once the image passes through the layer, it will then pass through the pool layers that were created, which are responsible for ensuring that all the features are properly mapped and down-sample in order to reduce any conversational complexity that the model itself may have. Once this was done, we were able to use various different activation functions in order to ensure that there was non-linearity among the layers. Completing this, we connected the line to the fully connected layers, which were able to map out the various features in order to establish output.

classes for the enhancement tasks. The final layer of our model with the output layer, which was responsible for providing the final image and its completely enhanced form. This was the architecture that we implemented in designing our model to ensure that it was able to accurately enhance the images. While this was the architecture we envisioned, we had to make sure that we made various changes in the layers during our training phase to ensure that the model was able to pick up the proper metrics.

Figure

1:



Proposed CNN Architecture

### 3.3 Training Our Model

Now that the architecture of the model has been completed, we cannot move on to training our model to ensure that he is able to properly and hand images. During the training phase, we had to use the training set that we had established by passing the label data through it and optimizing the parameters that we had established in the various layers. We used various different loss functions which were able to work effectively with the images that we had for enhancement. Once the training had been complete, we had to redo the training multiple times by optimizing the model, using various different optimization algorithms to ensure that it was in its most optimal form. Through this process, we constantly monitor the performance that our convolutional neural network displays by using metrics such as PSNR and SSIM along with the accuracy. Whenever we were able to understand that there was a dropout of the functions or weight decay, we had to regularize the model in order to ensure that overfitting was not taking place. Through the stage, we are able to effectively train the model in order to ensure that it was able to enhance the images with the highest accuracy possible.

### 3.4 Testing and Evaluation of Our Model

Now that the training was complete, all we had left to do was use the testing set which we had previously stored separately during our pre-posting stage and validate the performance of the model by using unseen data and finally refining it. Since the model was not working with unseen data. We were able to properly fine-tune the hyper parameters such as its own learning rate and batch size based on the performance that it displayed. We were also able to look into how the model itself performed on different diverse situations that can take place underwater to assess what we needed to change within the model. Through this process, we were able to ensure that the model was able to effectively enhance images irrespective of the underwater conditions by comparing it to existing approaches, and the results that we were able to obtain. As you can see in the next stage of our paper, we will display the results that we were able to obtain in the creation of our model.

## 4 Results

Overall, we are very satisfied with the results that we obtained during the enhancement of images using our convolutional normal network. We were able to effectively create high quality images, which can be used by various fields for their own work. You would like to display our findings below with the various results that we were able to obtain from our convolutional network. The enhanced images demonstrated an average PSNR of 18.64 dB, indicating a significant reduction in noise compared to the input images. SSIM scores averaged 0.3836, reflecting the structural fidelity maintained during enhancement. Furthermore, UIQM values were found to be 5.9315, highlighting the improvement in underwater-specific visual quality. Figure 1 displays sample images with their corresponding metric scores, showcasing the efficacy of the proposed method. The results for `set_f42.jpg` reveal that while the PSNR value indicates substantial noise reduction, the SSIM score shows room for improvement in structural fidelity. However, the high UIQM score underscores the model's success in enhancing underwater image features, such as color correction and contrast adjustment. These outcomes suggest the model's effectiveness in underwater-specific contexts while highlighting potential areas for further refinement in maintaining structural integrity.

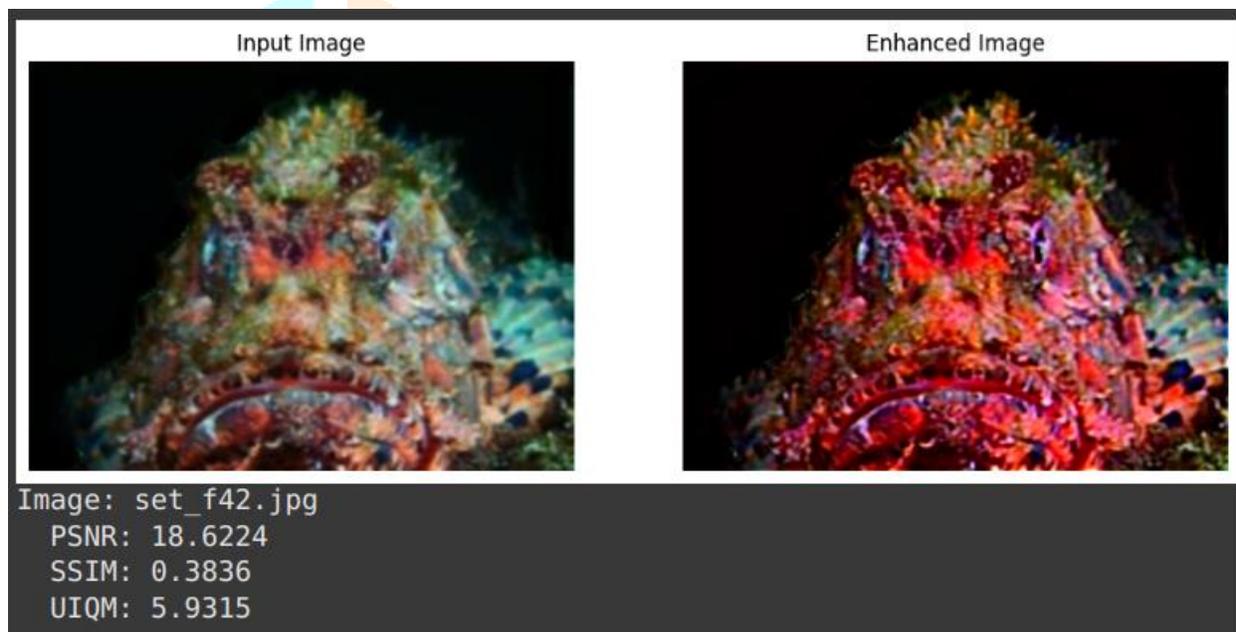


Figure 2: Image Enhancement Results with Metrics



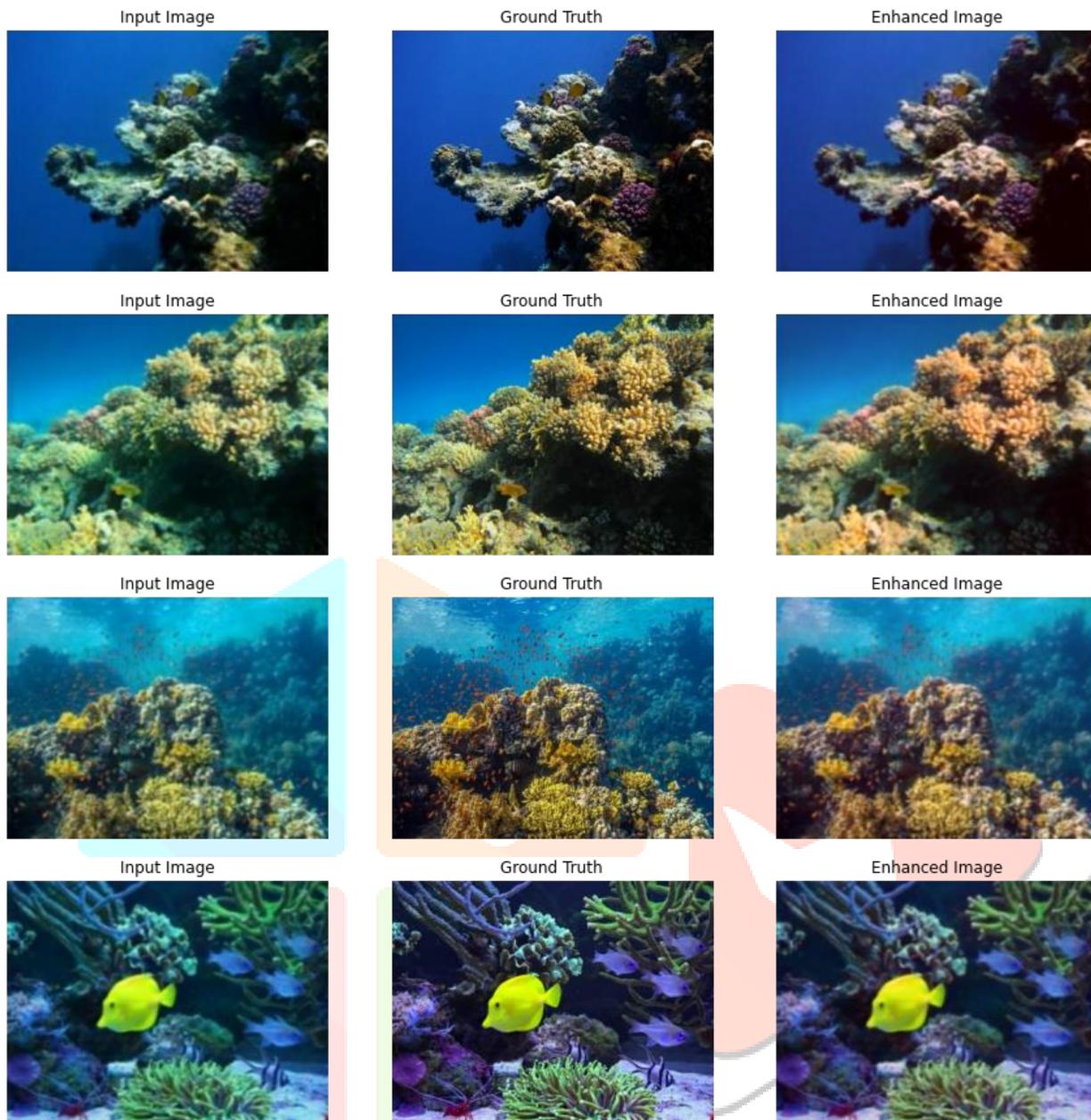


Figure 3: Image Enhancement Results

## 5 Conclusion

Through this project, you were able to learn many things, including the importance of underwater images. While this may be overlooked, many people do not seriously look into the problems that take place when we are dealing with images that are taken in the depth of the ocean. Another major factor that many people don't take into account is how light can be scattered and absorbed when it is passing through different mediums, which can cause many issues as we have discussed when trying to obtain high-quality images. During the creation of our model, we were able to learn how to effectively create various layers and how to hyper tune them to ensure that the enhancement was being done properly even with the various underwater scenarios. Overall, we are very satisfied with the convolutional no network that we created, and we hope that it can be used in various different industries across the world and helping them further research they do. We believe the studies will also be able to help various different industries in the future by equipping them with the various technologies that they create. While underwater robotics are still being recently brought into the modern world, we believe that with the help of models, such as the one that we were able to create, it will be able to bring in far better results when their task is to survey specific underwater environments. This can be used in both marine biology in order to study areas,

different aquatic life, and environment or even in various different real-world industries where they have to constantly monitor the various infrastructure that they have to build in the water itself. Overall, we hope that in the future, our methods can be further improved using new machine learning models, as well as optimizers in order to overcome the issues that we face today to create a model of much higher accuracy close to perfection.

**Acknowledgments** We thank --- for a discussion on the framing of the project.

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