

# A Review on Underwater Image Enhancement Models, Datasets and Metrics

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**Abstract:** Exploration of the underwater world is still the direction we are heading. Underwater imaging remains challenging due to blurred visibility, color deviation, and low contrast. Underwater image enhancement (UIE) represents a fundamental yet critical research challenge in the field of computer vision. Despite continuous advancements in hardware and algorithmic methodologies, there remains a lack of comprehensive summaries in this domain. To address this, we provide an overview of the research progress in UIE from the following perspectives. First, we introduce the three mainstream categories of UIE algorithms, along with the construction of datasets, including paired and unpaired datasets. Second, we conduct model training and evaluate the performance on a unified dataset, presenting results from both quantitative and qualitative perspectives. Finally, by utilizing the enhanced datasets for object detection tasks, we observe that the evaluation metrics of image enhancement and object detection do not exhibit a positive correlation.

**Keywords:** Underwater image enhancement; UIE models; Underwater dataset; Metrics; Object detection.

## 1. Introduction

The ocean covers approximately 71% of the Earth's surface[1], and as terrestrial resources become increasingly depleted and explored, the importance of investigating the resources of the underwater world is steadily growing. In the context of aquaculture, fish farmers are tasked with monitoring the health and growth of cultured organisms by assessing characteristics such as size, shape, and color. This enables the early detection of diseases and abnormalities, allowing farmers to implement effective strategies to optimize production and minimize losses[2]. However, the use of low-quality underwater imagery presents a significant challenge for biomonitoring applications[3]. To address this, marine engineering and research increasingly depend on underwater imagery captured by Underwater Vehicles (UVs), allowing researchers to efficiently and accurately analyze complex underwater situations. In the face of possible damage to pipeline facilities on the seabed, such as gas[4] or oil pipeline leaks[5] or submarine cable breaks[6][7], operators can use UVs to locate and analyze the damage, so that the necessary measures can be taken early to reduce economic losses and environmental impacts. UIE can also be used for surveys of seabed topography and geological features as well as underwater archaeological excavations[8]. The color of underwater images and the contour of the target serve as important information, so how to improve the quality of the images is closely related to many fields of underwater research.

When light spreads in water, it will be selectively absorbed, especially in red. So, the color deviation is serious[9]. And there are always floating particles, plankton, dust, which lead to light scattering during underwater propagation, making the image appears blurred and turbid[10][11]. Combining the effects of the above points, the underwater image obtained by UVs using camera often have serious color distortion, and blurred images with poor contrast, which makes it difficult to be directly applied to related underwater research fields.

In addition to above factors, another major difficulty in UIE

techniques is lack of corresponding reference images. Due to the dynamic nature of underwater objects, it is almost impossible to capture blurry and clear image pairs at the same location[12], which makes supervised learning extremely difficult. Most of the current underwater datasets use the captured underwater images to be processed by enhancement algorithms to obtain the corresponding reference images.

The subsequent chapters of this paper are structured as follows: Chapter 2 describes the UIE models; Chapter 3 introduces the underwater datasets; Chapter 4 conducts image enhancement experiments, target detection task experiments and analyses the results; Chapter 5 concludes the contents of this paper and presents an outlook.

## 2. UIE Models

While advancements in underwater camera technology have improved image quality to some extent, digital image processing remains a more cost-effective and practical solution, as it can be implemented in software at a significantly lower cost compared to sophisticated imaging hardware. Since the introduction of digital image processing, significant progress has been made in the field of underwater image processing, enabling enhanced visual quality and broader applications. Currently, common UIE models are mainly classified into three categories according to generating clear image methods: non-physical models, physical models, and deep learning models.

### 2.1. Non-physical Models

Non-physical models are usually computing faster and performing operations at the pixel level.

Without accounting for the underwater imaging process, enhancement techniques may inadvertently distort the image structure and introduce artifacts[13]. A basic enhancement approach involves first restoring the colors through white balance correction[14], followed by the application of Histogram Equalization (HE) to improve contrast[15]. Zhang proposed an enhancement method that compensates for specific color channels and performs local white balance

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moves at a good pace and contains a few surprises along the way

**chapters and volumes volumes one piece wiki fandom** - Jul 05 2023

web this is a list of all current chapters of one piece arranged by volume both chapters and volumes are listed with appropriate titles comprising the original japanese text romaji transcriptions and english translations note the us title of each volume reflects the titles chosen by viz

*one piece volume 38 oda eiichiro amazon fr livres* - May 23 2022

web one piece volume 38 broché illustré 8 janvier 2014 sanji est monté à bord du train des mers afin de secourir robin de son côté sur l île menacée par l aqua laguna le reste de l équipage est parti à la recherche de luffy et de zoro

one piece volume 38 rocketman by eiichiro oda goodreads - Jun 04 2023

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*volumen 38 one piece wiki fandom* - Apr 21 2022

web el volumen 38 de one piece se titula rocket man la cubierta es de color naranja con el logotipo del título en un degradado de espectro marrón el nombre del autor está impreso en marrón

list of one piece manga volumes wikipedia - Aug 26 2022

web the series spans over 1000 chapters and as of july 2023 has 106 tankōbon volumes making one piece the 22nd longest manga series by volume count the series has been translated and released in multiple countries

**one piece chapter 38 one piece manga online** - Feb 17 2022

web one piece japanese ワンピース hepburn wan pīsu is a japanese manga series written and illustrated by eiichiro oda it has been serialized in shueisha s weekly shōnen jump magazine since july 22 1997 and has been collected into 94 tankōbon volumes

*one piece vol 38 9781421534541 kitap arkabahce com tr* - Nov 28 2022

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*chapters and volumes one piece wiki fandom* - Dec 30 2022

web a guide to the overall organization of the one piece manga for specific numbered chapter and volume listings see the volumes tab the one piece manga is initially published as a serial in shueisha s anthology magazine weekly shonen jump this magazine as suggested by its title releases a

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web one piece bölüm 1038 kid ve law koca ana ya karşı oku 1 15 one piece bölüm 1038 kid ve law koca ana ya karşı manga oku

**volume 38 one piece wiki fandom** - Oct 08 2023

web volume 38 is titled rocketman the cover is of an orange color with the title logo being in a brown spectrum gradient the author s name is printed in brown the cover features monkey d luffy atop the rocketman while biting down a large chain behind him kokoro is posing with chimney and

**one piece volume 38 eiichiro oda archive org** - Aug 06 2023

web aug 23 2023 after the straw hats recover from their injuries they discover that robin has sided with the government in order to save the rest of the crew from destruction