Enhancing 3D Reconstructions in Underwater Environments: The Impact of Image Enhancement on Model Quality

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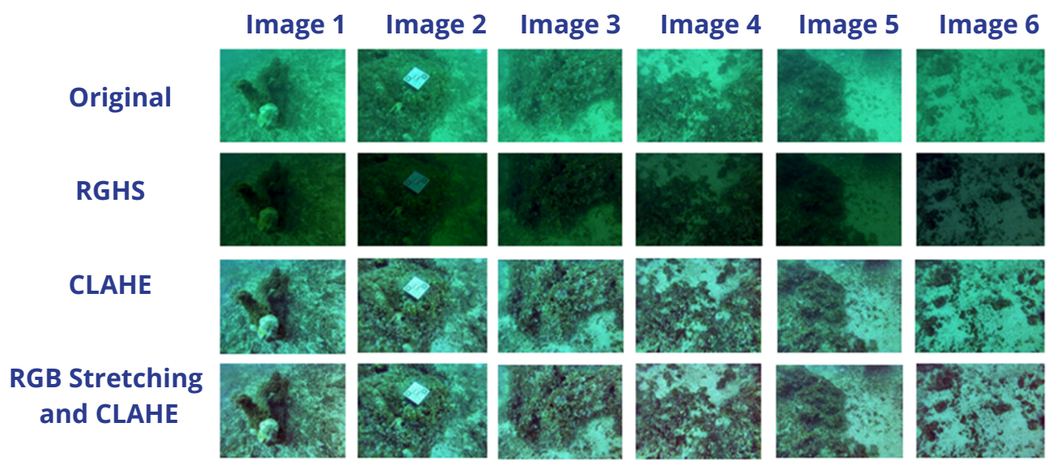
🎯 MOTIVATION

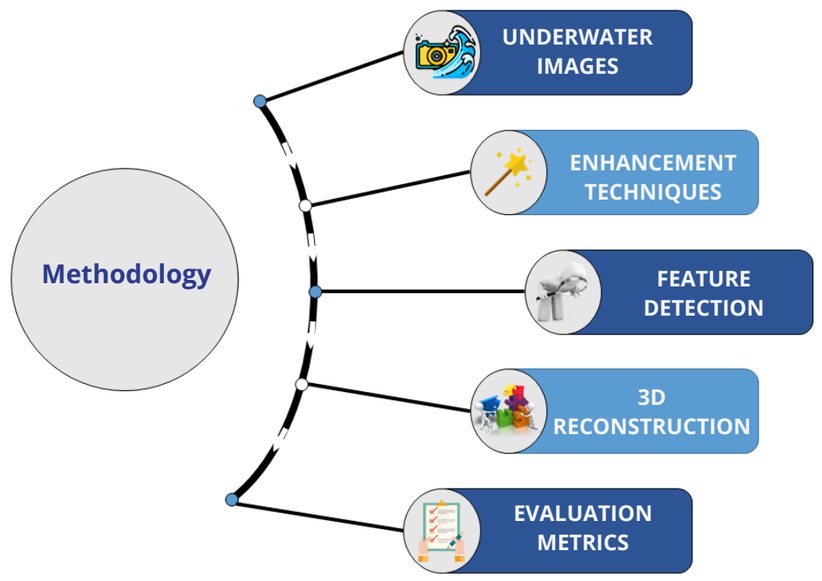
Underwater 3D reconstruction is important for **marine archaeology**, **ecology**, and **inspection** tasks. However, image quality is often **degraded** by blurring, low contrast, and color distortion. These issues reduce feature detectability and reconstruction accuracy. This study **investigates** whether image **enhancement** techniques can **improve** 3D model **quality**, focusing on their actual **impact on reconstruction performance** rather than just visual appearance.

🔨 METHODS COMPARED



METHODOLOGY

The workflow begins with underwater image **acquisition**, followed by the application of **three enhancement techniques**. Enhanced images are processed using **OpenSfM** for 3D reconstruction, including **feature detection**, **matching**, and **point cloud generation**. Results are evaluated using three metrics to **assess** the **impact** of each **enhancement** technique on **reconstruction quality**.



DATASETS

Three **real-world** underwater datasets were used, varying in **depth**, **turbidity**, and scene **complexity**, to evaluate the **generalizability** of each enhancement method.

METRICS

RP: Reconstructed Points
DF: Detected Features
RF: Reconstructed Features
These quantify **how** enhancements **affect** model **completeness** and **accuracy**.

RESULTS

Method	Dataset	RP	DF	RF
Unprocessed	A	762.431	14.563	6.156
CLAHE	A	836.012	17.321	7.033
RGHS	A	691.507	11.977	5.039
RGB-CLAHE	**A**	**846.060**	**18.149**	**7.535**
Unprocessed	B	435.918	12.290	5.883
CLAHE	B	446.378	12.566	5.941
RGHS	B	405.403	11.401	5.416
RGB-CLAHE	**B**	**469.433**	**13.240**	**6.498**
Unprocessed	**C**	**264.790**	**13.556**	**2.991**
CLAHE	C	235.625	12.581	2.716
RGHS	C	225.567	12.911	2.556
RGB-CLAHE	C	258.693	12.078	2.931
Unprocessed	Total	1.463.139	40.409	15.030
CLAHE	Total	1.518.015	42.468	15.690
RGHS	Total	1.322.477	36.289	13.011
RGB-CLAHE	**Total**	**1.574.186**	**43.467**	**16.964**

CONCLUSION

The **fusion** of **RGB Stretching** and **CLAHE** produced the most **consistent** improvements in 3D reconstruction across **multiple underwater datasets**. It **increased** the number of **reconstructed points** and enhanced **feature detection**. However, its effectiveness **varied** depending on scene **complexity**. These results **highlight** the **importance** of selecting **enhancement** methods based on **dataset characteristics** to **optimize** reconstruction **quality** in underwater environments.

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