Understanding The Impact Of Water Clarity When Scanning With The ULS-100

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Introduction

Visibility in underwater environments varies significantly. Since the ULS-100 Underwater Laser Scanner is an optical system, the performance of the system in an underwater environment is affected by the water clarity in that environment. The ULS-100 has silt filtering algorithms built into the system to mitigate the impact of water with a high silt content. This paper demonstrates the performance of the ULS-100 in a variety of water clarity conditions.

ULS-100

The ULS-100 Underwater Laser Scanner is designed to operate in harsh underwater environments where measurement data is required. This sensor can obtain data for anything from assessing the structural integrity of damaged or aging infrastructure to scientific and archaeological research. The ULS-100 operates by emitting a line of laser light onto the target surface and then calculating the relative position of hundreds of points along the line, creating a 3D profile of the target line. The head of the sensor can then mechanically step to capture adjacent profiles of data to build a complete 3D and dimensionally accurate point-cloud representation of the environment.

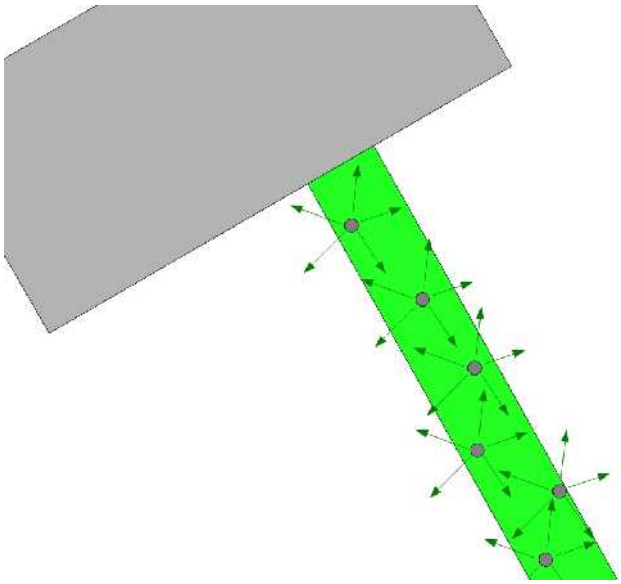
Impact of Silt in the Water

Turbidity is a measure of the cloudiness of water: water with a high silt content (low visibility) has high turbidity. However, describing the behaviour of light as it passes through water is not easily described by a single turbidity value. As light is transmitted through the water it is scattered and absorbed by the particles. Both scattering and absorption reduces the total laser intensity reaching the target surface, and scattering has the added problem of creating false returns at locations other than the target surface itself.

Scattering occurs by the light reflecting in all directions off of the particles in the water. The size of the floating particles has an impact on the scattering characteristics of the light. With many smaller particles in the water the light will scatter relatively uniformly and the scatter pattern will be consistent over time. Fewer but larger particles will scatter light in a more variable manner.

Depending on the material of the particles the absorption will be different. Water with primarily floating inorganics such as sand and minerals will have different absorption characteristics than suspended organics.

Ultimately, the light transmission characteristics of an environment can not only be characterized by the turbidity value of the water as size of particle and the makeup of the particles has an impact. For the purposes of demonstrating the performance of the ULS-100 in turbid conditions, a qualitative comparison between the scan quality and image quality is presented.



Scattering: suspended particles in the water reflect laser light in all directions

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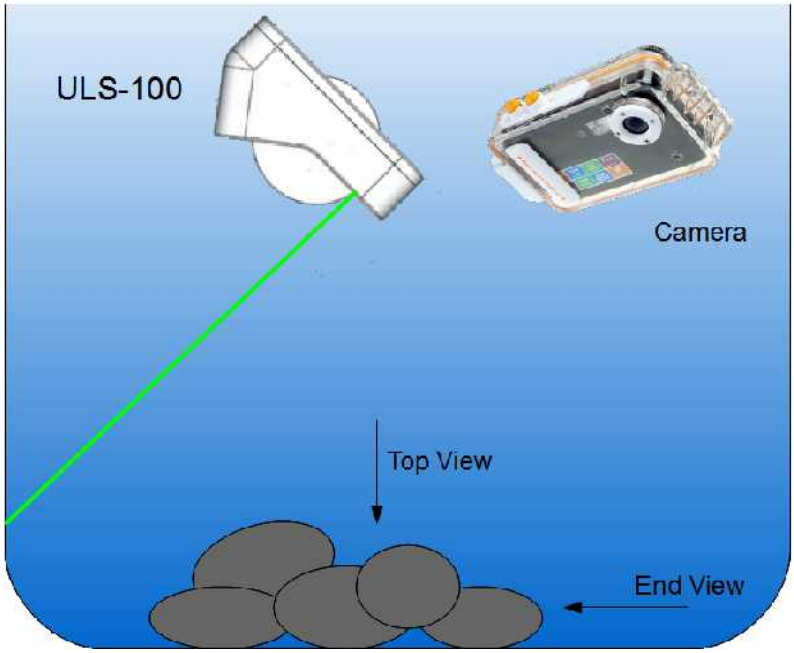
Results

The test target selected for this demonstration is a cluster of 1” to 2” stones positioned at the bottom of a small plastic bin used as a test tank. The scanner head was positioned approximately 12” from the top of the stones and pictures of the stones were taken from immediately beside the scanner head. Fine topsoil particles were mixed with the water to increase the turbidity for each scan and image combination presented.



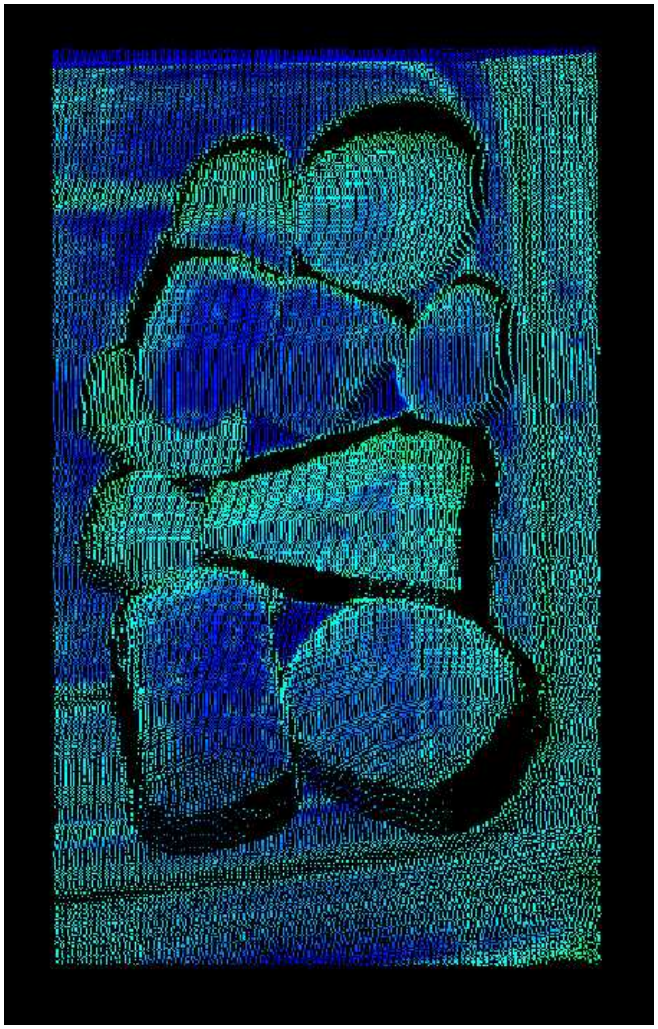
Side View / Section View of the Test Tank

In the results presented below a single image is shown for each of the silt levels and three views of the scan captured at the given silt level is also presented. The Side Views shown below are from the same perspective as the schematic of the tank above. The Top and End View directions are also indicated above. 3D animations of the scans are included in the video presentation of this paper found on the 2G Robotics YouTube channel.

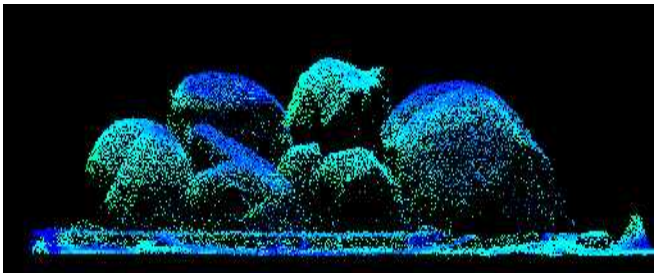
No Silt

A picture of the stones was taken before clear potable (tap) water was added to the plastic tub and the baseline scan was performed with water in the tub but no added silt.

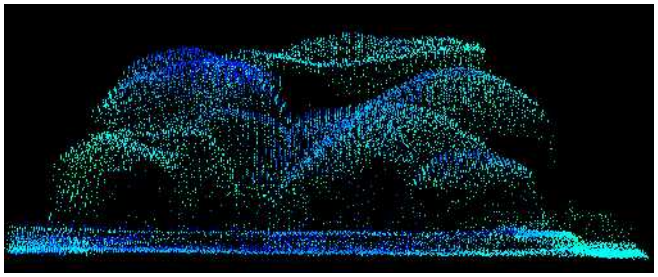
Cluster of stones in the tub before adding water.



Top View



Side View

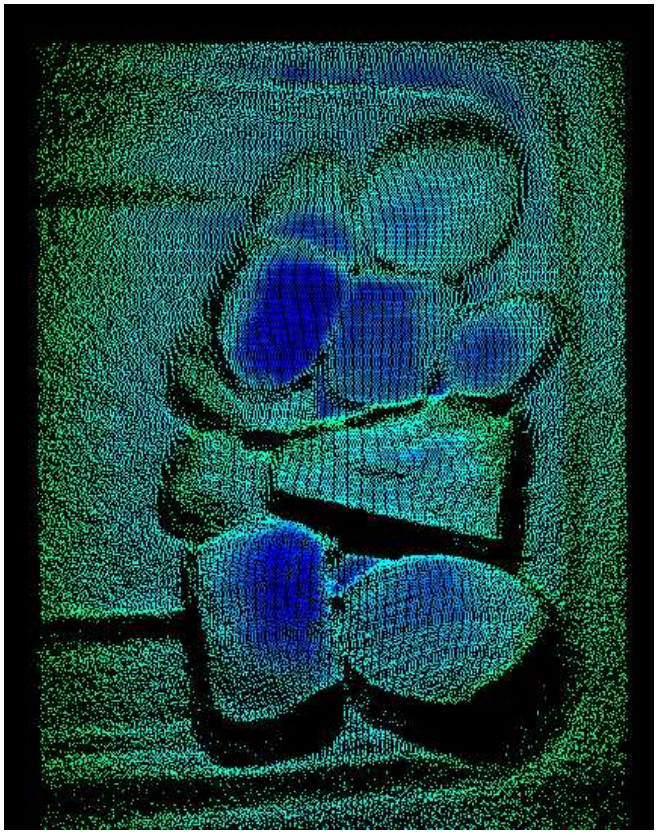


End View

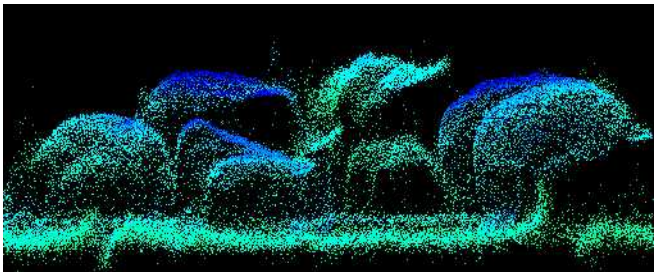
Silt Level 1

Top soil was mixed with the water to increase the silt content. The image of the stones is significantly more cloudy as a result. The scan data has degraded compared to the no silt condition: particularly, there is more variability to the points representing the bottom of the tub. The size and spacing of the stones relative to the tub and each other is still quantifiable.

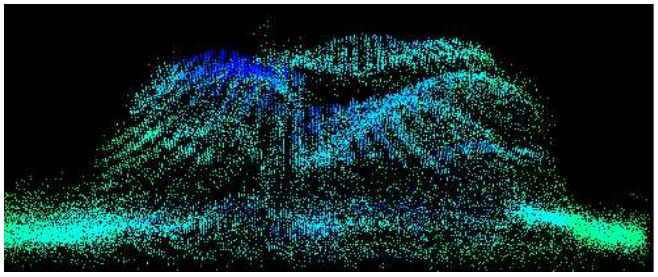
Stones with cloudy water



Top View



Side View



End View

Silt Level 2

The clarity of the water was further degraded by adding additional topsoil to the water. The picture of the stones and the accuracy of the scan is correspondingly degraded. In the top view of the scan data, the position of the stones is still clearly identifiable and quantifiable relative to each other. There are significantly fewer points defining the tub floor, and there is increasing variability (noise) in these points. From the end and side views, the mean position and size of the stones' surface is measurable but any details on the surface of the stones themselves is lost in the noise.

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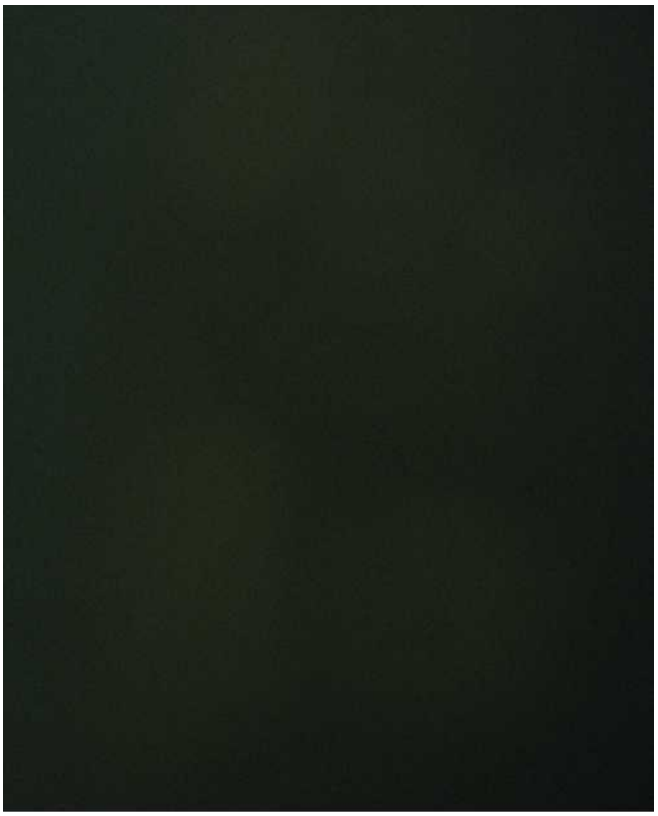
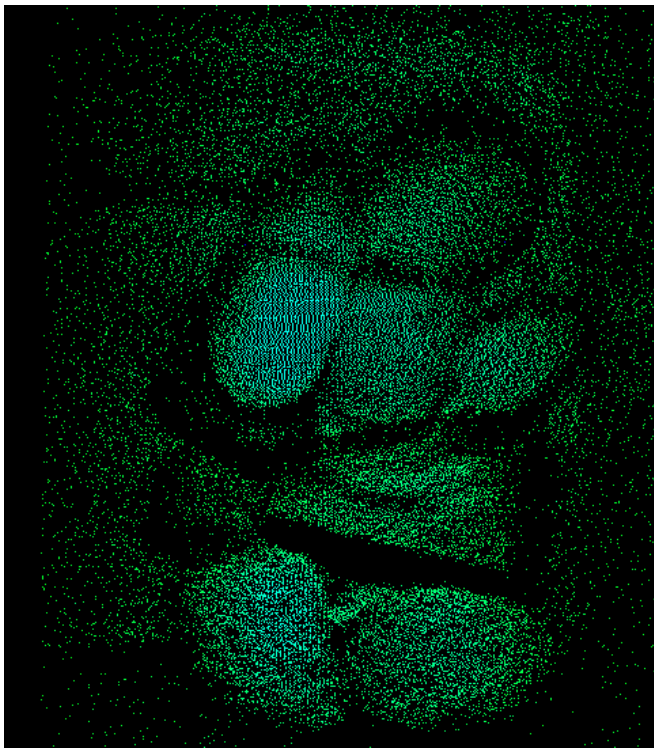
<td> 
Pictures of the stones in high silt.</td>
<td> 
Top View</td>
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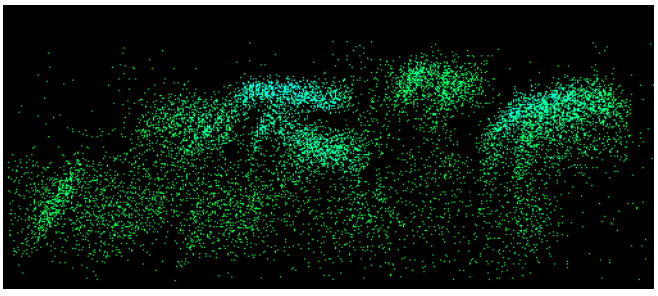
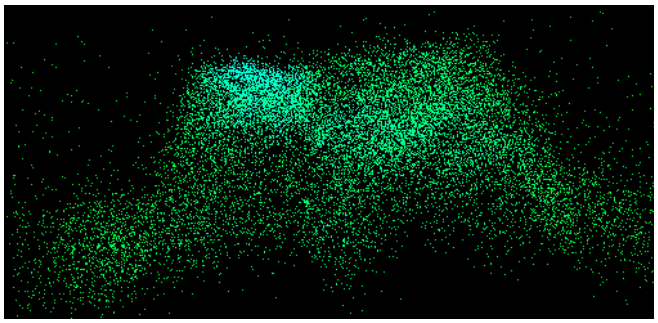
<td> 
Side View</td>
<td> 
End View</td>
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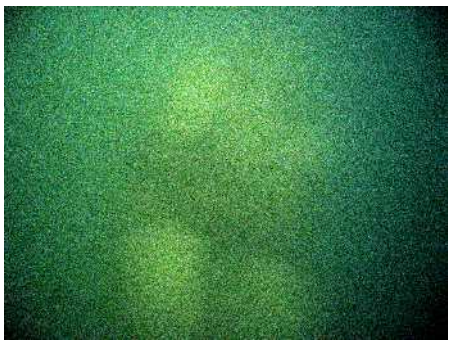
Silt Level 3

With further silt added to the water, the stones became almost impossible to see in the image. Through significant image processing, the stones can be seen, but the image is highly noisy.

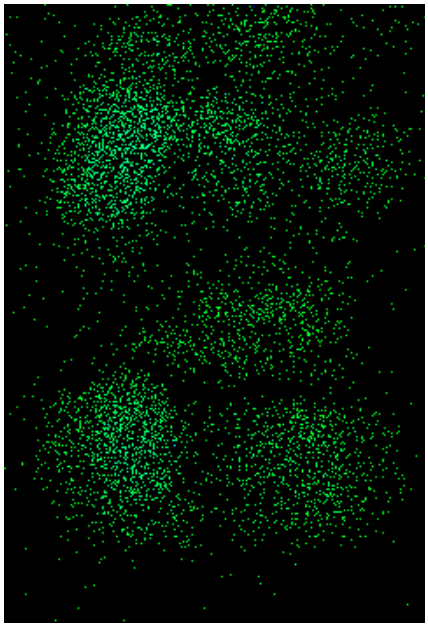
Raw Image



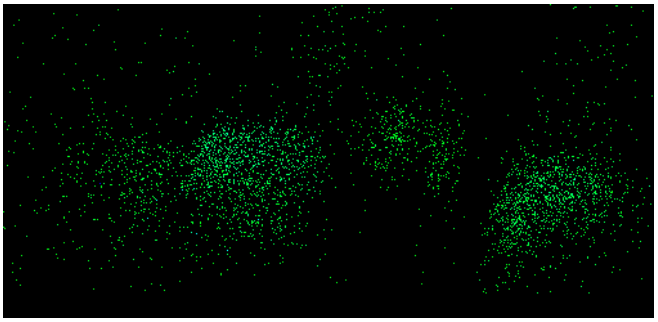
Processed Image

With effectively zero visibility, the ULS-100 is able to provide some level of data. The general location of the stones relative to each other can be identified. However, the edges of the stones are very poorly defined and only a crude understanding of the shape and size of the stones can be determined.

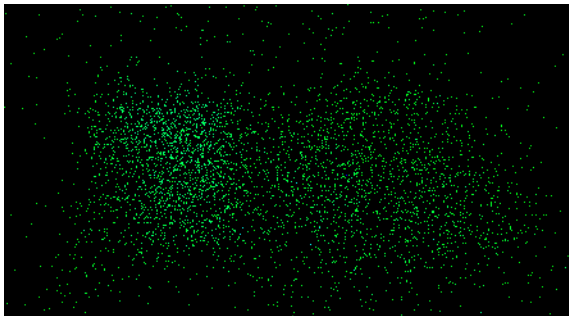
Processed picture in near zero visibility



Top View



Side View



End View

Conclusions

The performance of the ULS-100 will degrade as the clarity of the water degrades, and in general if you can get decent imagery (pictures) in an environment you can get a decent scan. The ability of the ULS-100 to operate in a turbid environment is highly dependent on the application the scanner is being used for. If the ULS-100 is being used to simply detect the location and general size of an object a significantly lower water quality is required than if fine details of an object are being measured.

The filtering algorithms employed by the UlS-100 do not presume anything about the environment. Further application specific filtering is feasible if further assumptions can be made about the objects and environment being scanned.

Contact 2G Robotics to discuss your application and specific silt conditions.

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