Creation of a 3D Printed Coral Reef Diorama

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Abstract- Coral reefs play a significant role in underwater ecosystems. Unfortunately, due to both natural and human pressures, coral reefs are currently facing many survival challenges. In an effort to discuss modern approaches towards nature conservation, the International Union for Conservation of Nature (IUCN) hosts the World Parks Congress in ten year intervals, with the next Congress being held in November 2014. We aim to produce a diorama of coral reefs for the World Parks Congress to assist observers in understanding the effects of nature and human actions on coral reefs. Data was acquired from a previous imaging and mapping project, *Reactive Reefs*, where images underwent *Fluid Lensing* to remove distortions caused by surface wave movements and enhance resolution. We produce our first 3D printed interpretation of coral reefs found in American Samoa and discuss methods that can provide improved results. The final product will include a scaled up version of our model and will utilize a pico-projector to project the coral reef texture directly onto the model. Future work includes repeating the process to generate a physical model for stromatolites found in Hamelin Pool in Western Australia, another subaqueous region of interest.

1. Introduction

The main purpose of this project is to create a 3D printed portable display of coral reefs that are found surrounding Ofu island in American Samoa. The display is to be taken to the International Union for Conservation of Nature (IUCN) World Parks Congress later this year. The IUCN primarily focuses on nature conservation, nature governance, and finding solutions to our current environmental and developmental challenges. The 2014 World Parks Congress aims to create a forum on protected areas and discuss knowledge and innovative approaches for nature conservation in the coming years.

A growing concern involving coral reef habitats has sparked interest in researchers who are worried about how human actions and climate change affect the areas. Coral reefs, often referred to as the "rainforests of the sea," are responsible for oceanic biodiversity, coastal protection, and tourist attractions[1]. Corals and anemones live in mutualistic symbioses with single-celled algae in which the algae provide nutrients produced by photosynthesis to the host in exchange for both shelter and certain chemicals that they need. The algae live within coral and anemone cells and they are what give them their colors. Increasing ocean temperature and pollution cause "bleaching", whereby the corals or anemones lose the algae from their tissues and thus their coloration. Without these symbiotic organisms the host animal struggles to survive, and, unless the process is reversed, will die.

The completed coral reef display will ultimately serve to tell the story of "bleaching" and bring observers into the underwater world to discover how the coral reefs change as a result of both natural and human pressures.

2. Methodology

Video and image data of the coral reefs were obtained last year by an interdisciplinary student group from Stanford University as part of the *Reactive Reefs* imaging and mapping project. Data underwent *Fluid Lensing*, an algorithm which seeks to remove strong optical distortions and enhance angular resolution in fluid-optical systems[2]. As a result, the first dataset of a reef system with sub-cm-level imagery in 3D was generated. Imaging the same scene at various angles resulted in 3D reconstruction of the reefs with the help of professional GIS software. *Fluid Lensing* results from UAV-based mapping of coral reefs are shown in Figure 1.

Manipulation and modeling of the 3D surface is done in an open source 3D animation suit, Blender, to create a hollow self-standing display of the coral reef topography. The final printed product will reach dimensions of approximately 30cm x 36cm x 8cm and will be housed within a hard plastic traveling case. Alterations were made to the case to accommodate a pico-projector that projects the coral reef texture on the 3D printed model. A drill was used to create 2 holes, one at the front and back sides of the case lid, to keep a monopod in place to hold the projector. Black fabric was added to the interior of the case for aesthetic purposes.

A scaled down version, approximately 7cm x 10cm x 2cm, of the coral reef model was printed and shows promise for the final product. The set up of the case, projector, and model is shown in Figure 2.

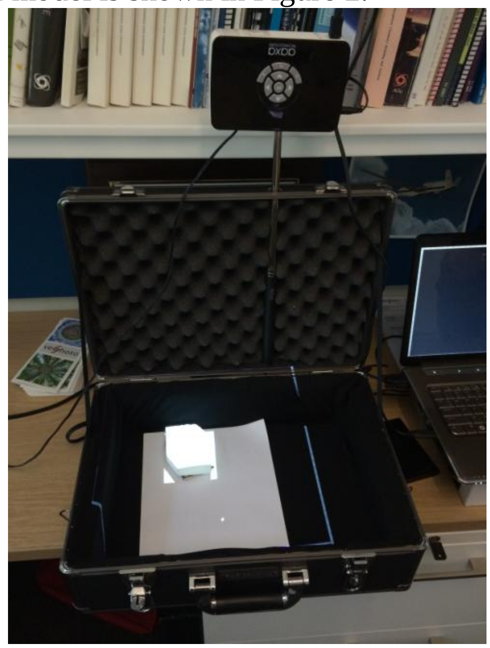

Figure 2 – Projector and model Set-Up for Diorama

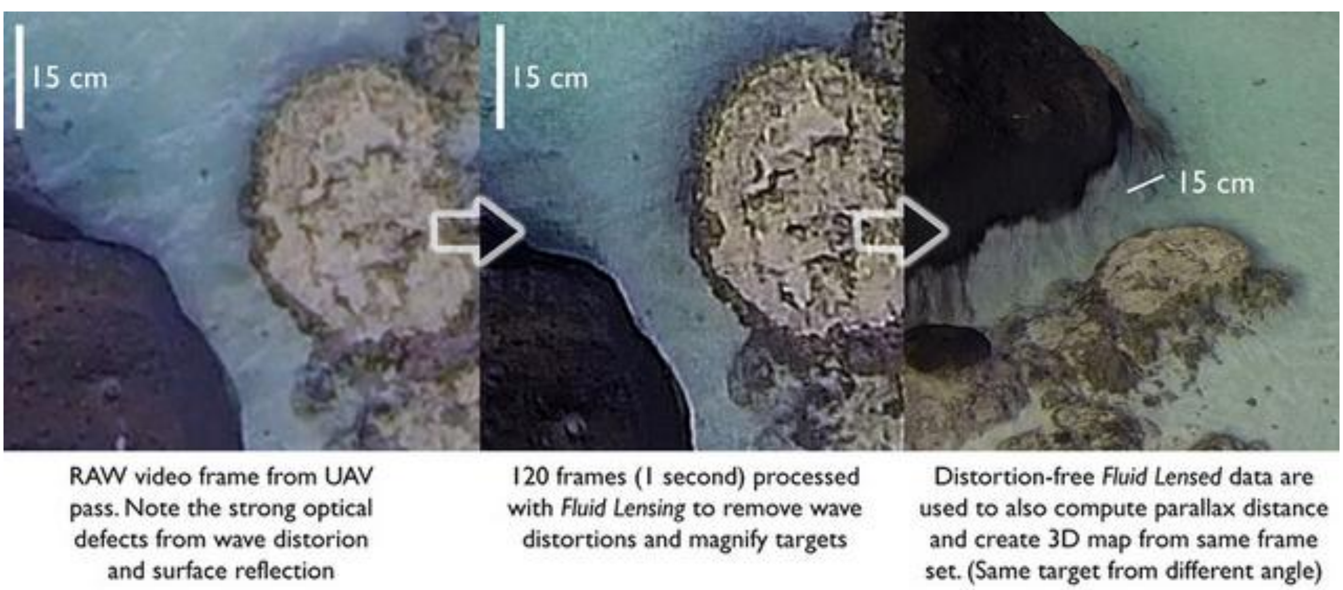

Figure 1- *Fluid Lensing* Results from Coral Mapping Mission in American Samoa

3. Experimental Results

3.1 Printed 3D Model

The scaled model was printed by an online 3D printing service. The result of the scaled down coral reef model is shown in Figure 3, along with comparison to its digital counterpart.

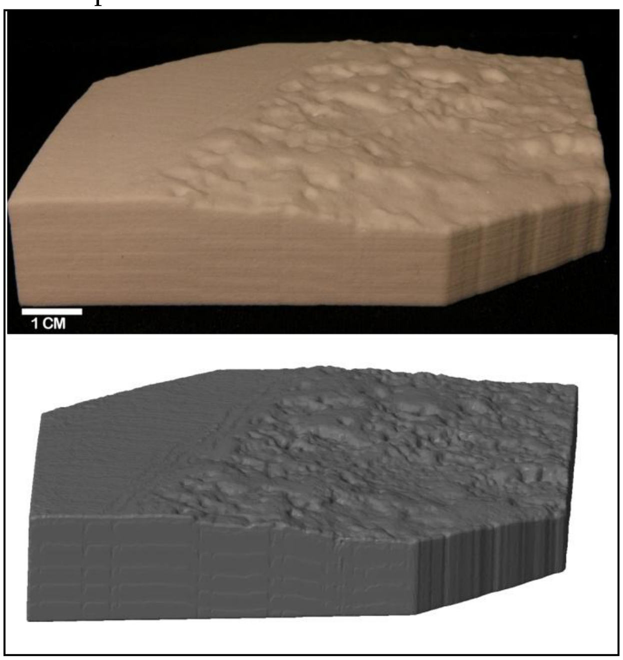

Figure 3- (Top) Oblique view of 3D printed coral reef model. (Bottom) Oblique view of computer model

In the model, the topography is inverted (i.e. the hills represent the ocean floor while the valleys represent the corrals) which is believed to have occurred when the model was first imported into the modeling program and misinterpreted. Detail was lost due to the thickening of walls that was necessary to produce a stable printable model. Detail was also lost in the modeling stage with the decimation of the 3D mesh prior to printing to adhere to the 1,000,000 face limit placed by the online 3D printing service

3.2 Coral Reef Texture Image Mapping

The ultimate goal is to project the images of coral reefs onto the model to create an interactive display for observers. This is achieved by projecting the orthographic photo of the reefs onto the model.

By mirroring a laptop screen through the projector and opening the ortho-photo in an image-editing program, the ortho-photo was scaled to the same size as the model and distorted to fit the surface of the model. For the small model, it was easier to physically move the model to fit the image when needed. Although not much freedom is granted to physically move the larger model, the same method can be used. To remove the dependence of an external laptop, the distorted image may be saved onto a microSD card and then placed directly into the projector. The ortho-photo for the small model was projected onto the model and results are shown in Figure 5. Due to the low resolution of the photo, it is easiest to distinguish the ocean floor and corrals by just their blue and brown colors respectively.

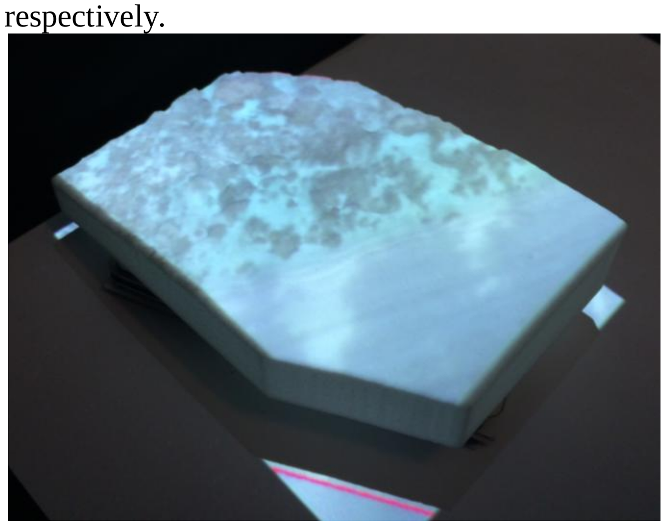

Figure 5- Texture Image of Coral Reefs Mapped onto 3D Printed Model

4. Discussion and Conclusion

Although the final product has yet to be produced, our experimental scaled down model shows promise for the final display. There is an alternate method that can potentially yield improved results. Loss of quality in order to fulfill printing requirements proved to have a significant impact on the final model. A similarly sized model that displays fewer points of interest from the coral reef, instead of a large map, will generate a model with more distinct features even with a decimated mesh. Alternatively, the z-axis of the model may be scaled to exaggerate the features of the model. A model with greater detail coupled with an ortho-photo at higher resolution will result in an accurate coral reef display.

Future Work

A diorama will also be created to represent stromatolites found in Hamelin Pool in Western Australia. Results from an aerial survey effort in American Samoa and Hamelin Pool show applicability of *Fluid Lensing* to large-scale automated species identification and morphology studies. The diorama for Hamelin Pool stromatolites will serve to display the various classifications of stromatolites.

Acknowledgments

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References

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2. www.vedphoto.com/reactive-reefs, www.vedphoto.comm/fluid-lensing