Wrigley Field Program Final Project
Project Proposal

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1 Proposed Titles

The proposed project can take on a few potential titles which will be selected at a later date based on the nature of significant findings. Each title emphasizes a different facet of the project.

- Computer Aided Analysis of Coral Bleaching in Amateur Photography
- Deep Learning Methods in Coral Bleaching Analysis
- A Comparison of Human and Computer Performance in Coral Bleaching Analysis
- CHROMA - Coral Health: Reef Observation, Measurement, and Analysis

2 Project Goals

The proposed project centers around the use of a color card to evaluate the extent of bleaching in Hawaiian coral reefs and aims to accomplish three major goals:

1. Evaluation of variance in human perception of color with respect to the use of the Hawaiian Ko'a Card in quantifying bleaching in Hawaiian coral species.
2. Development of a computer application to automate analysis of bleaching in images of Hawaiian coral species.
3. Improvement of citizen science methods with respect to coral bleaching analysis.

More detailed subgoals are listed in the Methods section as they provide an outline for the small sub-problems needed to be solved to accomplish the three major goals above.

3 Background

The primary motivation for the project stems from the rise of citizen monitoring and surveillance of environmental factors that serve as markers for ecosystem health. In particular, this project centers on the monitoring of coral reef health by quantifying the extent of bleaching in coral specimens. Coral bleaching is a phenomena in which corals expel their symbiotes during periods of stress, such as periods of high temperature or sunlight, causing the the entirety or parts of the coral to die. Such events are spatially large in nature and affect the reef ecosystem which is highly diverse and productive. Furthermore, such events are exacerbated by global climate change and therefore will be expected to occur more frequently. [5] Citizen monitoring has proven to be an invaluable tool in helping detect and quantify such events in a timely and large scale manner. [8] Analysis of the extent of bleaching in corals can be cumbersome and costly, often requiring special equipment that require training to operate. The use of color cards to compare coral colors by humans is a cost-effective and easy-to-use alternative to more expensive methods. The development of one such card for corals near Australia has been successful and more recently, a Hawaiian-specific coral color card has been under development. [2] Though cost-effective, variations in human color perception can render data gathered via human comparison to be inconsistent. Modern computer vision techniques [1] [3] [6] and deep learning methods [7] [4] have placed coral detection and color extraction in the realm of tractable problems. The details of such techniques are outside of the scope of this proposal but will be described in detail in the final work. Employing such methods and comparing them to traditional human-collected data to analyze and compare coral colors to the reference colors on the color card will be an important question the proposed project will aim to answer.

4 Hypotheses

In relation to the project goals stated above, the following hypotheses are proposed:

1. Significant variance in color rating by humans will be observed in the use of the Hawaiian Ko'a Card. This result will motivate the development of a computer application for more consistent and accurate color analysis for coral bleaching.

2. The use of deep learning methods and modern computer vision techniques in the digital analysis will allow more consistent and accurate color analysis for coral bleaching.

3. The development of a computer application can increase effectiveness of coral reef monitoring and promote submission of citizen driven reports to monitoring agencies.

5 Methods

Below are a set of sub-goals or sub-problems that must be solved to accomplish the three major goals of the project. The answers to each are located directly below and provide a step-by-step outline of the methods used in the project. Due to timeline constraints, the terms human participants or citizen scientists in this document will refer to college aged students participating in the Wrigley Field Program in Hawaii 2018. The author recognizes that such a participant pool is not representative of the general human population in terms of age, education, and training. However, recent citizen science programs have included introductory training seminars, helping decrease discrepancy in observations and collection methods which parallels the level of training the project participant pool will possess. Additionally, differences in color perception among the general population are studied in present literature and the findings from the project can be placed in context as such. Therefore, results from the project can still prove useful to a larger potential pool of citizen scientists despite the limitations of the participant pool.

1. Evaluate hue perception performance among human participants.
   > A set of human participants will be issued an online hue comparison test to be completed within a five minute window to survey color perception differences.

2. Develop field data sheet to facilitate use of Ko'a card for participants.
   > Development of a field incorporating location, weather conditions, time, color rating, coral morphology, and suspected corals species will be given to human participants.

3. Production of color-consistent/accurate Ko'a Cards for field use and digital analysis.
   > A professionally printed Ko'a card has been graciously donated by the Coral Reef Ecology Lab for use in the project. Further cards can be printed or reproduced, however the immediate needs have been met as of this proposal.

4. Develop field protocol for coral identification by humans.
   > A protocol to select coral specimens for human surveying controlling for variables such as depth, species, field traversal method, etc will be developed.

5. Develop field protocol for coral specimen photography in the field.
   > A protocol to capture images of coral specimens for digital analysis controlling for variables such as perspective, depth, camera settings, scene layout, etc will be developed.

6. Gather sufficient data points of human color ratings.
   > Human surveying of one or multiple field sites under different lighting and weather conditions will be conducted.

7. Gather sufficient images of associated coral specimens rated by humans.
   > Photography of specimens in one or multiple field sites under different lighting and weather conditions will be conducted.

8. Quantify variance and performance among participant color ratings of coral specimen.
   > Statistical analysis will be conducted both on data collected by humans.

9. Calibrate color in specimen images for comparison consistency.
   > A color correction or calibration method will be chosen and implemented to adjust for light attenuation and distortion in underwater photographs.

10. Localize and segment coral in images, optionally labelling them via texture classification.
    > State of the art localization, segmentation, and classification utilizing convolutional neural networks will be deployed in the image processing pipeline.

11. Develop method of extracting color values from coral images and determining color distance to reference hues.
    > An exploration of different color spaces, color distance metrics, and mean color extraction will be conducted to produce the highest fidelity comparison of extracted coral color to reference hues.

12. Associate coral health status and metrics to color values.
    > Association of metrics such as zooxanthallae counts and chlorophyll level with respect to coral color will be conducted.

13. Evaluate performance of digital and human methods of coral health analysis.
    > Statistical analysis will be conducted on computer performance in color analysis and compared to human performance.

14. Evaluate areas to further automate or improve digital analysis workflow and implement
    > As stated.

15. Implement feature to produce useful output products for reef health monitoring, such as a report.
    > As stated.

16. Document and release application via accessible channels or media.
    > As stated.

6 Logistics and Materials

Material costs are relatively limited assuming equipment and materials are avaialable from the Marine Biology module.

- Use of Underwater Cameras ($0)
- Waterproof Paper and Printing Cost ($0)
- MacBook Air Magsafe 2 Charger ($83.28)

The author will require drop-off and pick-up at various reef sites for brief surveying. The author will likely be able to join other groups on their field excursions or beach visits depending on location. Variety of location is not as critical as variety in lighting conditions and weather - thus multiple trips to a site previously visited during the Marine Biology module (Puako, Lapakahi, Captain Cook Memorial, etc.) would be sufficient for the proposed project. A proposed three trips on different days to any of these sites would be sufficient.

7 Schedule

Most of the work for the proposed project will occur digitally, thus only a few field excursions will be needed. Preliminary work on the application and a set of images have already been gathered. As of now, at least three days should be provisioned to drop the author off in the morning at Puako Bay or Lapakahi. Though the author will be unavailable to gather field data from December 2nd to December 6th, field work conducted in late October, early November, and late November should allow sufficient time to gather remaining data between December 7th and December 10th. A schedule of events is given below.

- Late October - Early November: Considerable application development, test images taken for image processing development.
- November 28th - November 30th: Development of field datasheets and protocols.
- November 30th: Online hue perception surveys conducted. Statistical analysis conducted
- December 1st: Morning field excursion to Puako Bay. Human ratings and images collected.
- December 2nd - December 6th: Application development and refinement.
- December 7th - December 10th: Field excursions to Puako Bay and Lapakahi. Statistical analysis conducted.

References

[1] D. Androutsos, K. N. Plataniotiss, and A. N. Venetsanopoulos, "Distance measures for color image retrieval," in *Proceedings 1998 International Conference on Image Processing. ICIP98 (Cat. No.98CB36269)*, vol. 2, Oct 1998, pp. 770–774 vol.2.

> Androutsos et. al. describe various color spaces and distance measurements in such spaces in this work, which is a critical measure needed to accurately find dominant colors and compare their similarity to a given palette such as the Hawaiian Ko'a Card. The authors suggest using the RGB color space with angle measurements to achieve the highest rate of similarity to human perception of color distance.

[2] K. Bahr, "Unpublished work - hawaiian ko'a card for coral color analysis," 2018, expected 2019.

> This work, though unpublished and existing only as a blog post on the Coral Reef Ecology Lab at the Hawaiian Institute for Marine Biology (HIMB) web page, is the primary motivation for my project. I plan to improve upon the use of the Hawaiian Ko'a Card by automating its analysis and providing a tool to ease its use for citizen scientits.

[3] M. Chow, R. H. Tsang, E. K. Lam, and P. Ang, "Quantifying the degree of coral bleaching using digital photographic technique," *Journal of Experimental Marine Biology and Ecology*, vol. 479, pp. 60 – 68, 2016. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0022098116300387

> Chow et al. describes a process of quantifying coral bleaching based on the whiteness of the specimen. I will use this work in tandem with data from the Ko'a Card to give and indicator of bleaching within a single photograph of a specimen.

[4] A. Gómez-Ríos, S. Tabik, J. Luengo, A. S. M. Shihavuddin, B. Krawczyk, and F. Herrera, "Towards highly accurate coral texture images classification using deep convolutional neural networks and data augmentation," *CoRR*, vol. abs/1804.00516, 2018. [Online]. Available: http://arxiv.org/abs/1804.00516

> This work describes the use of the state of the art Convolutional Neural Networks (CNNs) to classify coral texture images from two datasets, EILAT and RSMAS. They achieve results better than the previous state-of-the-art which involved intensive feature extraction processes by using an end-to-end CNN with two fully connected layers. I intend to use their method of classifying coral specimens - first by using transfer learning by pretraining a ResNet-50 on the ImageNet database and by replacing the last layer with two fully connected layers for Hawaiian coral species prediction. This would help predict coral species for images when the volunteer is unsure or lacks the domain knowledge to recognize species. Having a priori information of coral species can aid bleaching prediction. In order for this to succeed, I will require a labeled Hawaiian coral dataset and computational time to train the model (although the training cost will likely be reduced due to transfer learning).

[5] O. Hoegh-Guldberg, "Climate change, coral bleaching and the future of the world's coral reefs," *Marine and Freshwater Research*, vol. 50, no. 8, pp. 839–866, 11 1999. [Online]. Available: https://doi.org/10.1071/MF99078

This work discusses the effects of global climate change on coral reefs and their role in the mechanism of bleaching. I will utilize this work to motivate the problem at hand and the need for wide-scale, timely monitoring as global temperatures rise.

[6] D. G. Lowe, "Distinctive image features from scale-invariant keypoints," *International Journal of Computer Vision*, vol. 60, no. 2, pp. 91–110, Nov 2004. [Online]. Available: https://doi.org/10.1023/B:VISI.0000029664.99615.94

Automatic color correction of the image for accurate color representation requires a reference standard in the image. Often this would take the form of a color checker chart provided by companies such as XRITE or Munsell, which are cards that have a number of color chips that have calibrated color values. Since we cannot expect volunteers to have this on hand, we must find another reference set to succeed. Since the Ko'a Card itself is color calibrated with known values, we can utilize it as a color chart. In order to relieve the need for the volunteer to identify the location of the color card and to adjust for rotation, scale variance, and other affine transforms, we can utilize a feature matching algorithm that can be used to match a template image and give its location in the main image. This paper details the Scale Invarient Feature Transform (SIFT) algorithm that can identify the location of our Ko'a card. Doing so allows us to find the resulting color values subject to underwater distortion and apply a color correction algorithm. SIFT is an early work in this space and is considered a pioneering work but its age and its status as a patented invention will likely result in the project utilizing an open source and more recent successor. Nonetheless, this has been included in the bibliography as a reference standard.

[7] K. Maninis, S. Caelles, J. Pont-Tuset, and L. V. Gool, "Deep extreme cut: From extreme points to object segmentation," *CoRR*, vol. abs/1711.09081, 2017. [Online]. Available: http://arxiv.org/abs/1711.09081

Image segmentation is a computer vision problem in which pixels in an image are designated to be belonging to a certain class or object - essentially identifying the location an object occupies in an image. This work presents the state of the art in guided image segmentation. I intend to use this work to allow the user to refine the identification of coral specimen pixels when general localization fails to identify and isolate the specimen in question. The use of four points as guiding data for image segmentation is far less labor intensive than other efforts of edge scribbling or paint-style selection. In the case that a generalized coral localization and bounding box fails, I will default to using this work to isolate the coral specimen in question.

[8] J. E. Parkinson, S.-Y. Yang, I. Kawamura, G. Byron, P. A. Todd, and J. D. Reimer, "A citizen science approach to monitoring bleaching in the zoantharian *Palythoa tuberculosa*," *PeerJ*, vol. 4, p. e1815, Mar 2016. [Online]. Available: https://doi.org/10.7717/peerj.1815

This work details the difficulties and discrepancies in citizen science methods applied to coral reef health monitoring. In particular they detail variations in absolute color scoring by volunteers, variation in color in *Palythoa tuberculosa* colonies, and the briefness of training the citizen scientists obtained. My proposed project should help eliminate ambiguities and inconsistencies in color scoring by citizen scientists as well as alleviate the need for training before gathering data in the field. This work will be

used to motivate the need for the image processing tool as well as detail the potential pitfalls I will need to overcome when collecting my own field data.