Wrigley Field Program Final Project
An Annotated Bibliography

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Wrigley Field Program in Hawaii 2018

November 11, 2018

My 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. First, I aim to quantify variations in human perception and how such differences affect the use of color comparison instruments. Second, I intend to develop a computer application that can automate analysis of bleaching in images of coral specimens. The completion of the above mentioned tasks cumulate in the third and final goal of improving citizen science methods for ocean and coastline monitoring. The following papers present previous work on coral reef bleaching, color manipulation and analysis, and computer vision techniques.

References

[1] D. Akkaynak, T. Treibitz, B. Xiao, U. A. Gürkan, J. J. Allen, U. Demirci, and R. T. Hanlon, "Use of commercial off-the-shelf digital cameras for scientific data acquisition and scene-specific color calibration," *J. Opt. Soc. Am. A*, vol. 31, no. 2, pp. 312–321, Feb 2014. [Online]. Available: http://josaa.osa.org/abstract.cfm?URI=josaa-31-2-312

> This work motivates and reaffirms the use of commercial off-the-shelf (COTS) cameras such as point-and-shoots or GoPro devices to satisfiably produces images worthy of color analysis. The authors also supplement the work with tools to increase the fidelity of images captured. I will build on this work by automating calibration and using modern computer vision techniques to analyze coral bleaching.

[2] I. Analyst (MATLAB Forums User), "Background correction, color correction, and rgb-to-cielab calibration for color imaging devices," Dec 2016.

> User "Image Analyst" on MATLAB forums is a senior scientist at a top image processing company. In this presentation made avaialable on the MATLAB forums, he details a least-squares regression technique to correct RGB values to a known reference target. This work is critical in color correcting underwater images that suffer from changes in illumination, absorption of certain parts of the visible spectra, etc.

[3] 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.

[4] K. Bahr, "Unpublished work - hawaiian ko'a card for coral color analysis," 2018.

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.

[5] 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.

[6] 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).

[7] 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.

[8] 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.

[9] 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.

[10] 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.

[11] G. Winters, R. Holzman, A. Blekhman, S. Beer, and Y. Loya, "Photographic assessment of coral chlorophyll contents: Implications for ecophysiological studies and coral monitoring," *Journal of Experimental Marine Biology and Ecology*, vol. 380, no. 1, pp. 25 – 35, 2009. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0022098109003700

This paper presents a hardware and software method of analyzing coral photographs for bleaching quantification and presents a relationship between chlorophyll density in *S. pistillata* and the intensity of red color channel of coral surface photographs. The authors discuss drawbacks of hardware-driven methods and demonstrate the feasibility and effectiveness of simple underwater color correction via a color calibration instrument. This work, specifically the software method, is highly related to my intended project. My proposed methods, however, will improve over this work by automating segmentation of corals, increased versatility of color correction, holistic color analysis via bounding box partitioning, comparison to a color card specific to Hawaiian coral species, and automated reporting of results to the Eyes of the Reef network.