NYU TANDON SCHOOL OF ENGINEERING

Manta Rover: an Automated System for Coral Reef Remediation

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ABSTRACT

The Manta Rover system introduces new potential geo-engineering design experiments for local solutions to climate change. It brings up questions concerning artificial intelligence and experimental conservation technologies, and highlights using species-centered design as a way to consider small-scale solutions to problems created by climate change. By using targeted shading to mitigate effects of thermal stress to prolong the survival of coral communities, the Manta Rover introduces temporal mitigation measures until solutions to address global climate change become more effective.[1]

The Manta Rover filters the light that reaches the reef and uses image analysis with visible and hyperspectral bands to identify threatened coral ecosystems. The Manta Rover is programmed to automatically shade locations that are identified as threatened by the deep learning system that views the reef in real time using cameras attached to the floating shade. The system also identifies when the reef is healthy and the Manta Rover can move (through a GPS and propulsion system) and anchor to another location. The shading system is composed of an "optical fabric" that floats on top of the water and creates shade but is composed of dichroic filters, only letting the visible spectrum pass through (400 - 700 nm).

The project's goal is to provide a proof of concept of the Manta Rover by demonstrating the feasibility of implementing two essential components of the system: optical filters and machine learning models for coral recognition. The optical filters were tested in a small-scale experiment, employing artificial lighting, samples of the coral *Pocillopora damicornis*, and dichroic filters to assess the benefits of limiting the wavelengths on the coral. A deep neural network capable of automatically classifying coral images was developed using the BENTHOZ-2015 public dataset and the VGG16 architecture.[2, 10]

A case study aquarium experiment was set up using different light spectrums (full spectrum and visible spectrum) upon healthy specimens of the coral *Pocillopora damicornis*. We analyzed the effects of light stress by evaluating color changes using pixel-based image analysis of a series of photographs taken every ten seconds for the duration of the experiment. This experiment was designed to identify effects of manipulating the visible spectrum upon the coral as a way to partially limit the light frequencies, and identify the ideal limited spectrum that would compose the filtering system embedded in the larger Manta Rover floatation system.

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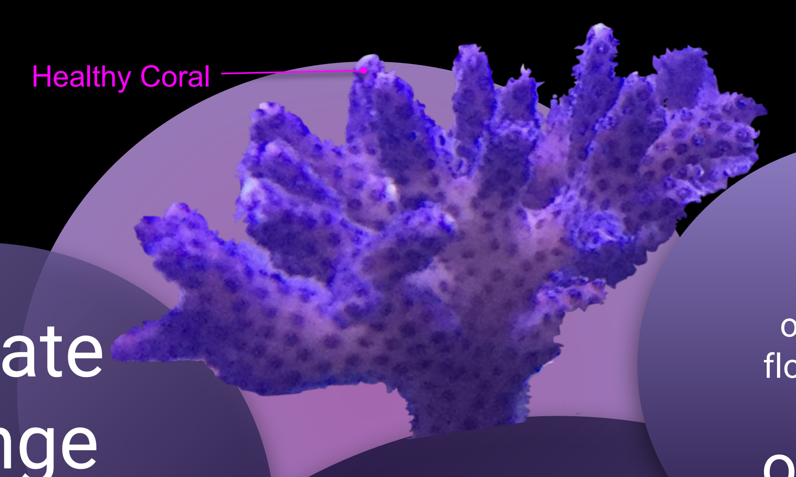
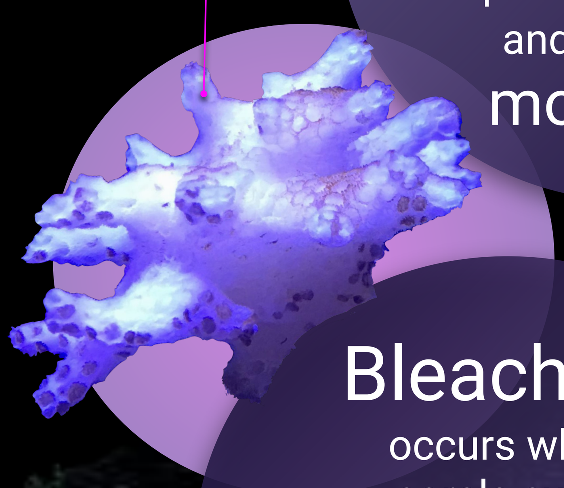




Climate change causes coral reefs to experience stress and increases mortality.[4]

Coral reefs cover 0.2% of the ocean's floor but sustain roughly one third of all marine species.[3]

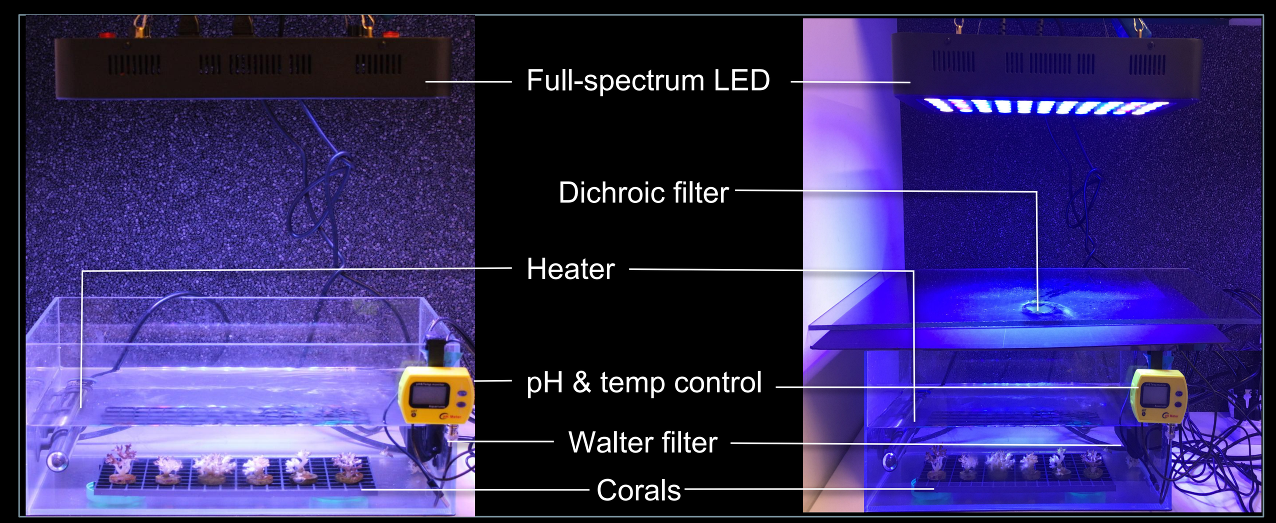
Why does bleaching occur?

1. Change in ocean temperature.[5]
2. Pollutants.[6]
3. Overexposure to sunlight.[7]
4. Altered ocean current.[8]

Bleaching occurs when corals expel symbiotic algae that carry out photosynthesis and is threatening corals.[9]

METHODS

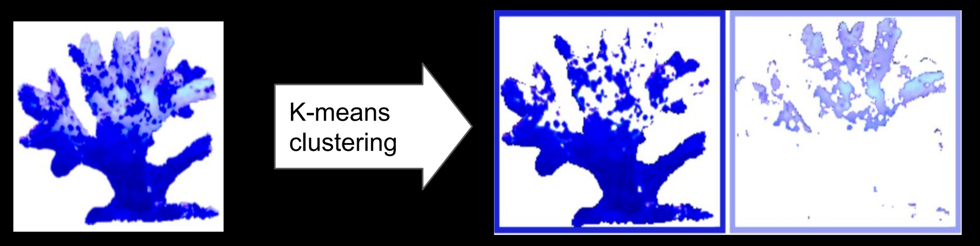
Experimental Setup



Control: full-spectrum light.

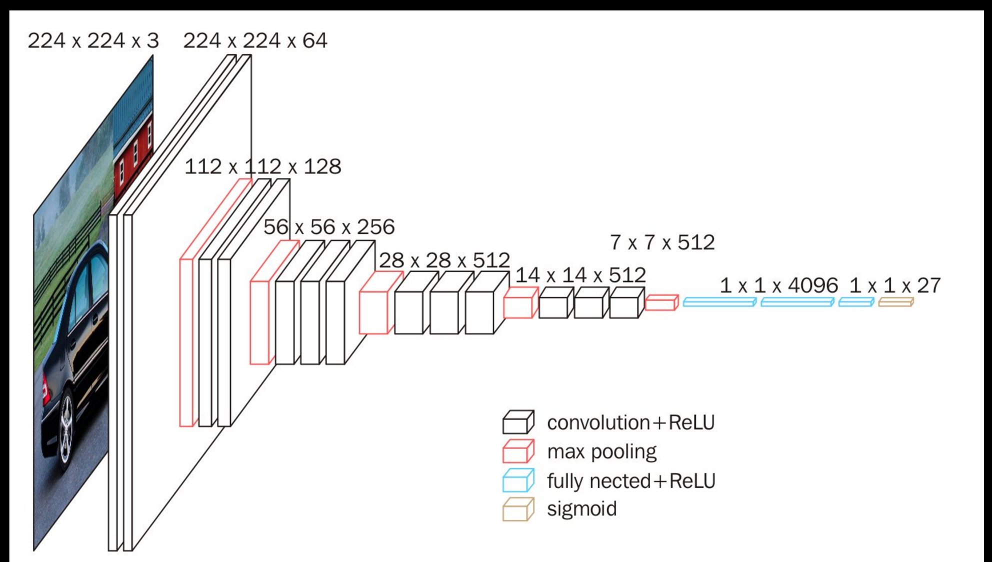
Experimental condition: light covered by dichroic filter.

Data Analysis

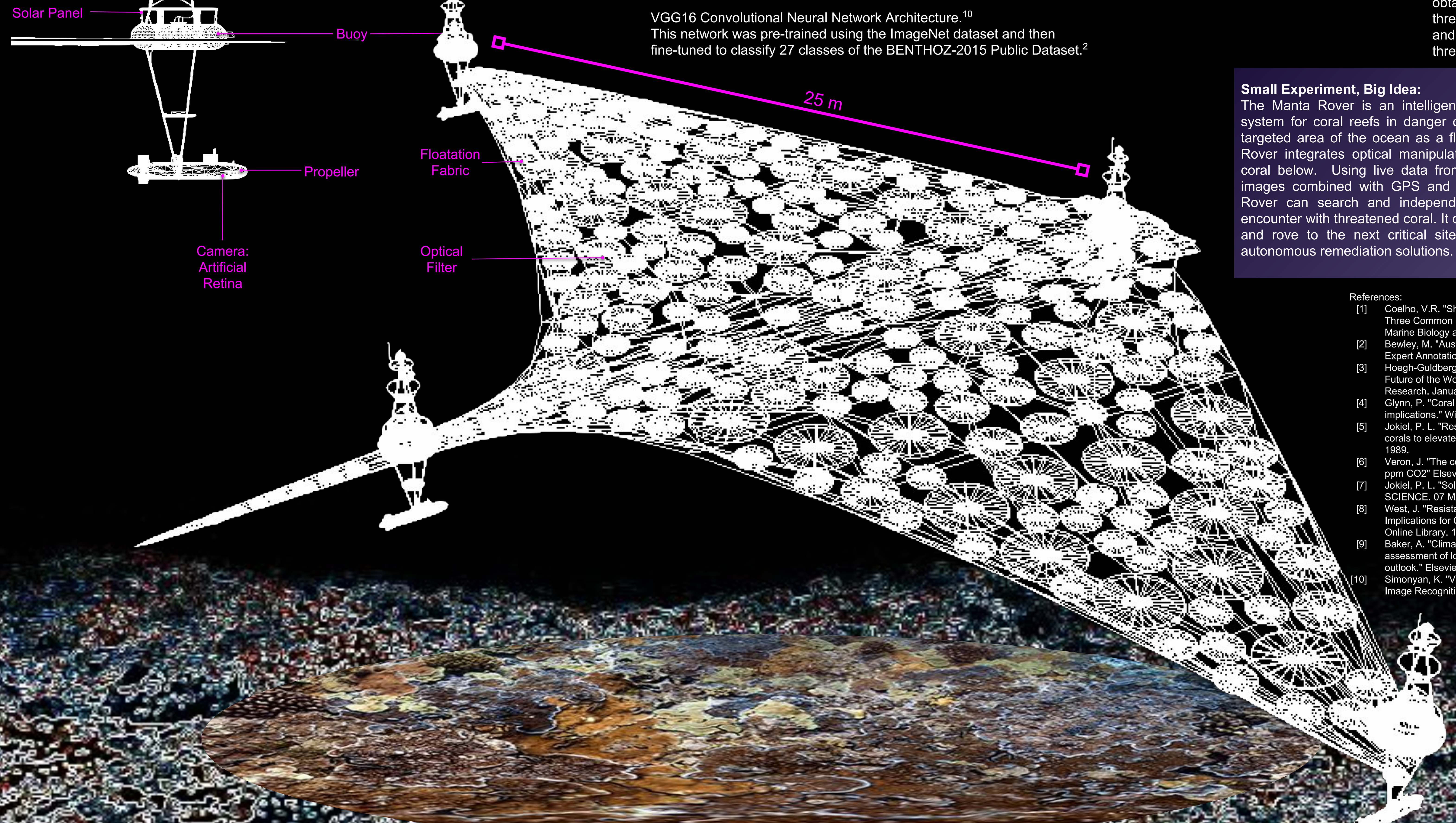


K-means clustering was utilized to classify pixels into bleached and healthy categories.

Deep Learning for Benthic Images Classification

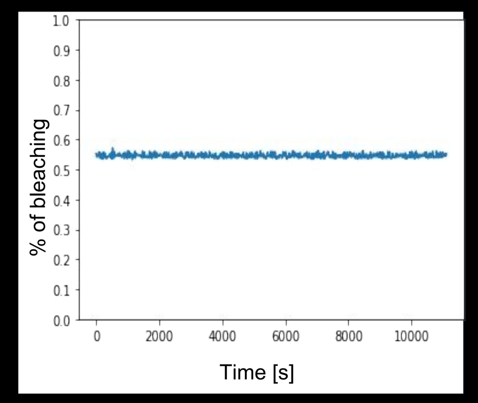


VGG16 Convolutional Neural Network Architecture.[10]
This network was pre-trained using the ImageNet dataset and then fine-tuned to classify 27 classes of the BENTHOZ-2015 Public Dataset.[2]



RESULTS

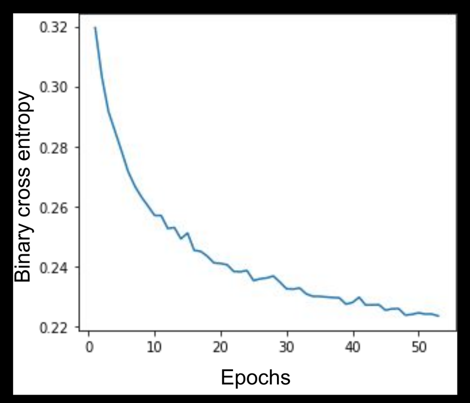
Bleaching Experiment



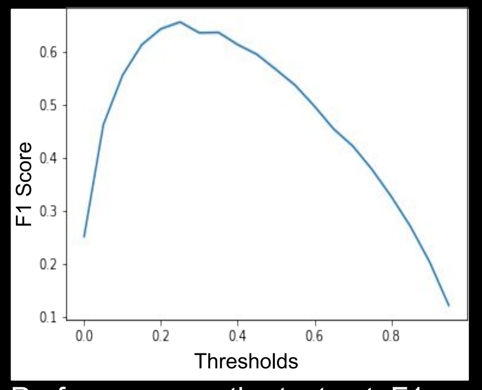
The experimental setup was tested by collecting data of the corals without introducing any experimental conditions. The goal was to verify that the corals' health remains unaltered without intervention. Results were averaged. Outliers (deviation greater than two standard deviations) were not included.

The graph supports that the corals did not experiment any changes in the absence of an introduced alteration. Further experiments employing the optical filters are currently in progress.

Deep Learning



The VGG16-based model was trained for 53 epochs. The graph shows that the binary cross entropy computed on the validation set drops, indicating the model improved with training.



Performance on the test set: F1 scores (weighted by sample) obtained using different thresholds. The optimal was 0.68 and it was obtained using a threshold of 0.35.

Small Experiment, Big Idea:
The Manta Rover is an intelligent, physical, and live remediation system for coral reefs in danger of bleaching. Stretching across a targeted area of the ocean as a floating optical surface, the Manta Rover integrates optical manipulation of visible light to shade the coral below. Using live data from a trained system of coral reef images combined with GPS and a propulsion system, the Manta Rover can search and independently position itself for a direct encounter with threatened coral. It can observe the status of the coral and rove to the next critical site on its own – working towards autonomous remediation solutions.

References:
[1] Coelho, V.R. "Shading as a Mitigation Tool for Coral Bleaching in Three Common Indo-Pacific Species." Journal of Experimental Marine Biology and Ecology. October 06, 2017.
[2] Bewley, M. "Australian Sea-floor Survey Data, with Images and Expert Annotations." Scientific Data. October 27, 2015.
[3] Hoegh-Guldberg, O. "Climate Change, Coral Bleaching and the Future of the World's Coral Reefs." Marine and Freshwater Research. January 01, 1999.
[4] Glynn, P. "Coral reef bleaching: facts, hypotheses and implications." Wiley Online Library. April 27, 2006.
[5] Jokiel, P. L. "Response of Hawaiian and other Indo-Pacific reef corals to elevated temperature" Springer-Verlag. September 06, 1989.
[6] Veron, J. "The coral reef crisis: The critical importance of <350 ppm CO2" Elsevier. October, 2009
[7] Jokiel, P. L. "Solar Ultraviolet Radiation and Coral Reef Epifauna." SCIENCE. 07 MAR 1980
[8] West, J. "Resistance and Resilience to Coral Bleaching: Implications for Coral Reef Conservation and Management." Wiley Online Library. 16 July 2003
[9] Baker, A. "Climate change and coral reef bleaching: An ecological assessment of long-term impacts, recovery trends and future outlook." Elsevier. 10 December 2008
[10] Simonyan, K. "Very Deep Convolutional Networks for Large-Scale Image Recognition." ICLR 2015