NEMO-NET - THE FLUID LENSING NEURAL NETWORK FOR GLOBAL CORAL REEF ASSESSMENT

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Old Dominion University

Coral Reef Airborne Laboratory

IUCN

Khaled bin Sultan Living Oceans Foundation

Mission Blue Sylvia Earle Alliance
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PI: DR. VED CHIRAYATH
1) Develop the most accurate algorithm for identification of coral organisms from remote sensing at different scales.

2) Globally assess the present and past dynamics of coral reef systems through a large-scale active learning neural network.

3) Quantify coral reef percent cover and spatial distribution at finest possible spatial scale.

4) Characterize benthic habitats into 24 global hierarchical classes, resolving coral families with fluid lensing at finest scales.
1) Developed malleable CNN architecture for scalable heterogenous computing architecture.
2) Created cloud masking CNN algorithm.
3) Implemented domain transfer learning for spectral and spatial resolution transfer learning (super resolution) across multiple sensors.
4) Created 3D active learning CNN training application in game interface for data training from multiple sensors.
OCEAN WAVE FLUID LENSONG PHENOMENON

Caustics

Fluid lenslets and evolution of caustics
## NEMO-NET DATA SOURCES

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Effective Spatial Resolution</th>
<th>3D</th>
<th>Spectral Bands</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underwater AUV</td>
<td>0.1 - 5 cm</td>
<td>YES</td>
<td>3</td>
<td>Australia, Great Barrier Reef, Pacific</td>
</tr>
<tr>
<td>FluidCam &amp; MiDAR (NASA)</td>
<td>0.1 ~ 2 cm</td>
<td>YES</td>
<td>3-8</td>
<td>American Samoa, Guam, Western Australia, Puerto Rico, Indo-Pacific</td>
</tr>
<tr>
<td>QuickBird (USGS)</td>
<td>0.65 m</td>
<td>NO</td>
<td>4</td>
<td>US Territories</td>
</tr>
<tr>
<td>WorldView-2/3 (LOF)</td>
<td>0.5 - 3 m</td>
<td>NO</td>
<td>8</td>
<td>Global</td>
</tr>
<tr>
<td>CORAL PRISM (NASA)</td>
<td>7 m</td>
<td>NO</td>
<td>248</td>
<td>Hawaii, Mariana Islands, Palau, Guam, Great Barrier Reef</td>
</tr>
<tr>
<td>Landsat (USGS)</td>
<td>30 m</td>
<td>NO</td>
<td>11</td>
<td>Global</td>
</tr>
</tbody>
</table>

**Imagery Examples:**
- **FluidCam**
- **QuickBird**
- **WorldView-2**
- **PRISM**
ACTIVE LEARNING FRAMEWORK

User Classified Data

Match with satellite data

Data Preparation
- Fill in gaps in user classified data (most common neighbor)
- Data normalization
- Label conversion
- Data randomization and augmentation
- Export image blocks to appropriate folders
- Export segmentation truth map

Prepared Data
- Training Image Data
- Training Label Data
- Validation Image Data
- Validation Label Data

To CNN
NEMO-NET PROTOTYPE DATA PRODUCTS
M-Scale Airborne Fluid Lensing & Satellite Data

MM-Scale Airborne Fluid Lensing DEM

M-Scale Airborne Fluid Lensing & Satellite Data

VR & App-based Active Learning & Interactive Training through IUCN, Mission Blue, & Partners

Level 1 Data & Existing Training Data Analysis

Active Learning Training of Coral Cover & Morphology Type

NeMO-Net Living Structure & Morphology Classification

NeMO-Net Ingestion of Multi-Modal Data, Data Fusion, & Training

NeMO-Net Living Structure & Morphology Classification

Science Partners

IUCN

Khaled bin Sultan Living Oceans Foundation

MISSION BLUE™ SULLYIA EARLE ALLIANCE
<table>
<thead>
<tr>
<th>Zone</th>
<th>Major Geomorphological Structure</th>
<th>Detailed Geomorphological Structure</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Level 5</th>
<th>Level 6</th>
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</thead>
<tbody>
<tr>
<td>Reef Crest</td>
<td>Coral Reef and Hardbottom</td>
<td>Reef Crest/Coralline Algae Ridge</td>
<td>Live Coral</td>
<td>Branching Coral</td>
<td>Acroporidae</td>
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<tr>
<td>Fore-Reef</td>
<td>Fore-Reef Deep Slope</td>
<td>Algae</td>
<td></td>
<td>Massive Coral</td>
<td>Agaricidae</td>
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<tr>
<td>Reef Flat</td>
<td>Fore-Reef Shallow Slope</td>
<td>Higher Plants</td>
<td></td>
<td>Octocorals</td>
<td>Astrocoeniidae</td>
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<tr>
<td>Back-Reef</td>
<td>Fore-Reef Shallow Terrace</td>
<td>Prokaryotes</td>
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<td>Macr algae</td>
<td>Merulinidae</td>
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<tr>
<td>Lagoon</td>
<td>Fore-Reef Octocorals-dominated</td>
<td>No Cover</td>
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<td>Turf Algae</td>
<td>Montastraeida</td>
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<tr>
<td>Bank/Shelf</td>
<td>Back-Reef Pavement</td>
<td>Unknown</td>
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<td>Coralline Algae</td>
<td>Mussidae (Faviidae)</td>
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<tr>
<td>Escarpment</td>
<td>Back-Reef Coral Framework</td>
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<td></td>
<td>Seagrasses</td>
<td>Poritidae</td>
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<tr>
<td>Channel</td>
<td>Back-Reef Coral Bommies</td>
<td></td>
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<td>Mangroves</td>
<td>Siderastreida</td>
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<tr>
<td>Dredged</td>
<td>Back-Reef Octocorals-dominated</td>
<td></td>
<td></td>
<td>Cyanobacteria</td>
<td>Meandrinidae</td>
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<tr>
<td>Lagoon</td>
<td>Lagoon Pinnacle Reefs</td>
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<td>Unknown</td>
<td>Pocilloporidae</td>
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<tr>
<td>Shoreline Intertidal</td>
<td>Lagoon Patch Reefs</td>
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<td>Pectinidae</td>
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<td>Salt Pond</td>
<td>Lagoon Fringing Reefs</td>
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<td>Fungidae</td>
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<tr>
<td>Inland Water</td>
<td>Lagoon Deep water</td>
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<td>Caryophyllidae</td>
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<td>Land</td>
<td>Unconsolidated Sediment</td>
<td>Fore-Reef Sand Flats</td>
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<td>Dendrophylliida</td>
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<tr>
<td>Unknown</td>
<td>Back-Reef Sediment-dominated</td>
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<td>Gorgoniidae</td>
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<tr>
<td>Other</td>
<td>Deep Ocean Water</td>
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<td>Plexauridae</td>
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<td>Seagrass Meadows</td>
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<td>Nephthidae</td>
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<tr>
<td>Intertidal Wetlands</td>
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<td></td>
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<td>Phylum Chlorophyta</td>
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<tr>
<td>Beach (Sand)</td>
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<td>Phylum Phaeophyta</td>
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<tr>
<td>Beach (Rock/Dark)</td>
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<td>Phylum Rhodophyta</td>
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<tr>
<td>Terrestrial Mangroves</td>
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<td></td>
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<td>Angiospermae</td>
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<tr>
<td>Terrestrial Vegetated</td>
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<td></td>
<td>Phylum Cyanophyta</td>
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</tr>
<tr>
<td>No Data/ Clouds/Unknown</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Unknown</td>
<td></td>
</tr>
</tbody>
</table>
In-game field guide

- Each class label will contain photos of typical species/genera.

- May vary depending on the geographical location of the image to be processed (e.g., Atlantic/Caribbean vs Indo-Pacific).
UPCOMING NASA NEMO-NET APP - 2019
NEMO-NET NEWS

PUERTO RICO FIELD CAMPAIGN!
Puerto Rico Field Mission

• March 6-18, 2019

• Concentrated on the southwest coast (La Parguera Natural Marine Reserve)

• 3 reef sites (legacy sites for previous NASA campaigns: 2004-2009; HICE-PR; CoralBASICS)

• Coordination with the University of PR – Department of Marine Sciences – Bio-optical Oceanography Laboratory (Dr. Roy Armstrong, Director)

• Collection of high resolution camera data for NeMO-Net
- Actually… 10x10m phototransects
- ~80% overlapping between photos
- > 5 phototransects per reef site
- Capture uniform and mixed areas
Typical waypoint sampling - video

- ~500-800 waypoints per reef
- ~1GB of data per waypoint
- ~2.3 cm spatial resolution


4) Guam Field campaign – May 2019 (last week!)

5) Palau Field Campaign – Sept 2019 before the 42nd US Coral Reef Task Force meeting

6) Several other publications under development
Thank you!