Pier Recognition: An *in situ* Plankton Web Camera
(Scripps Plankton Camera)

Paul L. D. Roberts, Jules S. Jaffe, Eric C. Orenstein, Ben Laxton, Peter J. S. Franks, Christian Briseño, Melissa Carter, and Mary Hilbern
Outline

• Scripps Plankton Camera (SPC) Development
• Preliminary Automated Image Annotation
• Summary And Future Work
Motivation

- Scripps Pier Time Series
  - A rich time series with a long history.
- Understanding and predicting the triggers of plankton blooms is still an open problem.
- There is a need for image data and rapid sampling/processing to improve our understanding of these processes.
SPC Imaging System Design Objectives

• A moderate cost ($10k-$30k) underwater, darkfield, microscope system.
• Use off-the-shelf parts supporting a wide range of customization of magnification and illumination.
• Image fragile plankton taxa without breaking them apart.
• Take advantage of modern embedded processors for low-power, real-time processing.
• Real-time, interactive data available to all via a modern web application.
- Dual-housing design allows for wide range of working distances
- Imaging lens and Illumination NA can be changed easily.
# SPC Imaging Performance

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field of View</td>
<td>25 mm x 20 mm</td>
</tr>
<tr>
<td>Resolution</td>
<td>7.4 μm pixels</td>
</tr>
<tr>
<td></td>
<td>35 lp/mm @ 40 % contrast</td>
</tr>
<tr>
<td></td>
<td>35 lp/mm @ 20 % contrast</td>
</tr>
<tr>
<td>Depth of Field</td>
<td>400 μm @ 35 lp/mm</td>
</tr>
<tr>
<td>Hi-Resolution Volume</td>
<td>0.2 mL per Frame</td>
</tr>
<tr>
<td>Blob-Detection Volume</td>
<td>10 mL Frame</td>
</tr>
<tr>
<td>Data Rate</td>
<td>Up to 8 fps with ROI processing</td>
</tr>
</tbody>
</table>

- **Calanoid Copepod Acartia**
- **caudal setae**
- **500 μm**

- **HiResol**

- **Volume**
  - 0.2 mL per Frame

- **BlobX Detection**
  - 10 mL Frame

- **Data Rate**
  - Up to 8 fps with ROI processing

- **Gray Value vs Distance (μm)**
  - 40 μm
Comparison With Lab Microscopy

Scripps Plankton Camera (*in situ*)
https://jaffeweb.ucsd.edu:5001

Scripps Institution of Oceanography Zooplankton Guide
https://scripps.ucsd.edu/zooplanktonguide/species/acartia-acanthacartia-tonsra
SPC Acquisition Software

- Raw images are acquired continuously at a given frame rate (up to 8 Hz).
- 9 megapixel images are down-sampled by a factor of 4.
- Down-sampled images are filtered with a Laplacian filter.
- Output of the filtered images are segmented and binary regions are detected.
- The original raw pixel values from the detected binary regions are saved to local disk or over the network.
Recent Addition:  
SPC-P: Microplankton Camera

<table>
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<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field of View</td>
<td>2.5 mm x 2.0 mm</td>
</tr>
<tr>
<td>Resolution</td>
<td>0.74 μm pixels 200 lp/mm @ 40% contrast</td>
</tr>
<tr>
<td>Depth of Field</td>
<td>20 μm @ 200 lp/mm @ 20% contrast</td>
</tr>
<tr>
<td>Hi-Resolution Volume</td>
<td>0.1 μL per Frame</td>
</tr>
<tr>
<td>Blob-Detection Volume</td>
<td>10 μL Frame</td>
</tr>
<tr>
<td>Data Rate</td>
<td>Up to 8 fps with ROI processing</td>
</tr>
</tbody>
</table>

![Image: Microplankton Camera](image_url)

Bacteriasterum spp.  
5 μm
Comparison With Lab Microscopy

Scripps Plankton Camera - P (in situ)
http://jaffeweb.ucsd.edu:5055

M. Hilbern and J. McGowan,
SCCOOS Harmful Algal Bloom Monitoring Program
http://www.sccoos.org/data/habs
Automated Image Annotation

• The ease with which data is collected by the SPC systems gives rise to a significant annotation challenge.

• There has been excellent work in addressing the problem of annotating images from a test set using a large training set (Sosik & Olson L&O Methods, 2007, Gorsky et. al J. Plank. Res., 2010).

• Here, we consider the problem of applying these algorithms to data over a long time series where the relative abundance of classes can change dramatically from the training data.

• We aim to build a framework that combines humans, machines, and available auxiliary data to yield accurate predictions for relative abundance from the SPC system targeted at specific scientific questions.
Annotating Framework

- **Auxiliary Data**
  - Automated Prediction with Archive Data Classifier (real-time)

- **Image Classification Task**
  - Specificity of Task

- **Hybrid Sampling With Guided Annotation Tools**

- **Manual Annotation with Guided Annotation Tools**

- **Archive Data Set (images with annotations)**
  - Low
  - Medium
  - High

- **Auxiliary Data**
Archived Data Classifier

- Built from the archive data set labeled by users of the website.
- Linear, one-vs-one, SVM with probability outputs (sklearn implementation).
- 75 features are selected from morphological descriptors for the ROI and gray-level co-occurrence matrix.
- Average of 80% to 90% correct classifications on test set (500 images per class).
- A perfect algorithm yields a diagonal confusion matrix (right).
Hybrid Sampling

• Task: Highlight a bloom of Helical Diatom Chains in May 2014.

• Framework:
  – Archive Data Set of 11,000 annotated images drawn from March through October 2014.
  – Train the SVM on these 11,000 images and then apply the SVM to annotate 1000 images sampled randomly for each day in May 2014.
  – Of the 1000 images each day, 100 images are randomly selected and manually annotated.
  – The bias of the SVM output for a given day is estimated using the 100 manual annotations and applied to adjust the SVM output on the 1000 images.
Daily Relative Abundance with Archive Data Only

Estimates from Archive Classifier

Days in May 2014

Relative Abundance

0-0.1
0.1-0.2
0.2-0.3
0.3-0.4
0.4-0.5
0.5-0.6
0.6-0.7
0.7-0.8
0.8-0.9
0.9-1.0

No Data
Daily Relative Abundance with Hybrid Sampling

Diatom Chain Bloom

Helical Diatom Chain Bloom

Estimates with Hybrid Sampling from 100 Samples

Days in May 2014
Comparison

Blooms not clearly evident in SVM only estimates

Hybrid Sampling cost is only 10% of manually annotating all 1000 images per day
Summary and Future Work

- Two prototype imaging systems were designed and developed to study temporal changes in the plankton community off Scripps Pier.
  - In 2015 we will deploy permanent versions of these systems for one full year.
- The task of annotating image data from these systems was explored in a hybrid sampling framework.
  - Hybrid sampling can offer significant improvements in our ability to detect blooms in these data with only a small (~10%) addition of manual annotations.
  - In 2015 we will further develop and test tools for rapid image annotation, prediction, and relative abundance estimation.
Acknowledgments

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• Collaborators
  – Southern California Coastal Ocean Observing System
  – Marine Science Development Center
  – Jaffe Lab Team

• Imaging FlowCytobot (Sosik & Olson)
  – Website: http://ifcb-data.whoi.edu/mvco

• SPC Websites (A work in progress; feedback is very welcome!)
  – SPC (Plankton): http://jaffeweb.ucsd.edu:5001
  – SPC-P (Microplankton): http://jaffeweb.ucsd.edu:5055