Making sense of seafloor images collected by autonomous robots

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Photo: Logan Mock Bunting
Underwater robot survey path

3D reconstructions from stereo

Accurate loop closures kilometers apart (SLAM)
1. Slide a window over the terrain

2. Compute surface area using triangles

\[ A = \sum_{j=1}^{J} a_j \]

\[ a_j = \frac{1}{2} \left| \begin{vmatrix} x_2 - x_1 & y_2 - y_1 & z_2 - z_1 \\ x_3 - x_1 & y_3 - y_1 & z_3 - z_1 \\ x_2 - x_3 & y_2 - y_3 & z_2 - z_3 \end{vmatrix} \right| \]

3. Fit a plane to the points using PCA

4. Project points onto plane and compute projected areas

\[ A' = \sum_{j=1}^{J} a_j (|\hat{p} \cdot \hat{n}_j|) \]

5. Compute rugosity, slope and aspect

\[ r = \frac{A}{A'} \]

\[ \theta = \cos^{-1}(\hat{p} \cdot \hat{k}) \]

\[ \psi = \tan^{-1} \left( \frac{p_x}{p_y} \right) \]

Measurement can be done at multiple spatial scales.

RUGOSITY clearly shows different habitat types.
Repeat surveys: day & night

Urchin Barrens in Tasmania
Day survey
no kelp, no urchins
Night survey
lots of urchins!
Repeat surveys across multiple years

Coral bleaching in Western Australia
Healthy coral

Bleached coral

Dead coral

Growing corals

Survey 2010: Peak temperature 26.4°C

Survey 2011: 251 consecutive days
MILLIONS of images collected for IMOS
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eg:
50 random pixels in
1% of collected images
=0.000035% of data analysed

eg:
ALL pixels in
ALL collected images
=100% of data analysed
Image acquisition & pre-processing

Manual human annotation

Segment images & compute features

Consolidate point labels & superpixels

Train superpixel classifier

Automated superpixel classification

Validate
  - Classification accuracy
  - Compare % cover

Extrapolate
  - Identify benthic biota
  - Estimate % cover
Ariell Friedman, (2013) **Automated interpretation of benthic stereo imagery.** PhD Thesis, University of Sydney
South East Tasmania

- 11 dives
- >100,000 images
- 20 clusters
- ~10 mins
Ecology
Archaeology
Geoscience

Methane hydrates, WHOI/ACFR, 2011/2013
Deepwater Horizon, WHOI/ACFR, 2010
Sicily, RPM/ACFR, 2011/2013
EV Nautilus (Caribbean), URI/OET/ACFR, 2013/2014
EV Nautilus (Med), URI/OET/ACFR, 2010-2012
Pavlopetri, Nottingham/ACFR, 2010/2011
Antikythera, WHOI/Argo/ACFR, 2014/2015

NOAA, Umi ch/Nottingham/ACFR, 2015
Antikythera, WHOI/Argo/ACFR, 2014/2015
Pavlopetri, Nottingham/ACFR, 2010/2011

Scott Reef, SOI/WHOI/URI/UH/ACFR, 2015
Lizard Island, St Andrews/UMacQ/ACFR, 2013-2015
Fukushima, UTokyo/ACFR, 2014
Artificial Hydrothermal, Tokyo/ACFR, 2014

IMOS
Artificial hydrothermal vents

Japan 2014
Submerged city of Pavlopetri, in Greece

Comparing stereo photogrammetry to traditional mapping methods

Archaeological map based on years of measurement

IVER AUV

AUV Surveys done in 3 days
Problem:

MANAGING DATA AND STANDARDIZING ANALYSIS
Future directions for squidle

• Support for additional platforms, data types & data sources

• Video annotation interface

• Automated machine learning tools & active learning

• Incorporate novel & flexible annotation schemes
Thanks to:

Schmidt Ocean Institute
Integrated Marine Observing System
The ACFR AUV team
& everyone in the picture below