Underwater video sampling: What's in an image?

Janine Guinan [1] , Margaret Wilson [1] , Anthony Grehan [1] , Katia Lebart [2] , David Redpath [2] , Colin Brown [1]

[1]Department of Earth and Ocean Sciences, National University of Ireland, Galway.
[2]Ocean Systems Laboratory, Department of Computing and Electrical Engineering, Heriot-Watt University, Edinburgh, UK.

Introduction

High resolution underwater video imagery when combined with remotely sensed geoacoustic imagery will improve our knowledge of the distribution of benthic seafloor habitats in the Irish offshore region. While acoustic imaging techniques provide valuable information on the physical properties of the seabed, underwater optical imagery reveal those characteristics of seafloor habitats relevant to monitoring and managing ecosystem health in particular for management of SACs (special areas of conservation). Interpretation of video and photographic imagery can be subjective and labour intensive, particularly for underwater video surveys generating large data sets. The value of collecting remotely sensed video data lies in the amount of information which can be extracted.

We will use underwater video imagery as a qualitative descriptor to classify seafloor benthic communities at the Irish continental margin based on their dominant physical and biological attributes according to existing deep-seafloor classification schemes. Following qualitative classification, quantitative information from video data will help establish species occurrence and species-environment relationships for statistical ecological modelling. The semi-automated classification of video imagery is being developed in an effort to reduce the amount of time and effort involved in processing video data. A number of constraints exist for the collection of underwater video imagery; cameras are mounted in forward facing and downward facing position on a Remotely Operated Vehicle (ROV) or towed vehicle array which is in constant motion, and as a result of this movement the camera field of view is continuously changing. Vehicle navigation and positioning must be accurate to ensure the *in situ* video stream is georeferenced. Spatial distortions due to camera angle, variations in lighting conditions and specific lens characteristics cause distance and scale inaccuracies which must be considered. The area of seafloor covered by the camera field of view (Fig. 2) depends on the altitude of the vehicle. Characterisation of benthic communities using video requires fine-scale resolution at the sub-metre scale. Optimum flying height above the seafloor for where features on the seabed can be resolved is ~ 3 - 5m.

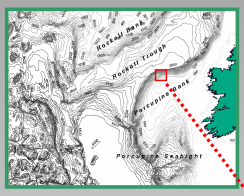


Fig.3. Location map with red box indicating area in SE Rockall Trough where underwater video images (below) were collected. Bathymetry contours from *GEBCO '03* at 100m depth intervals.

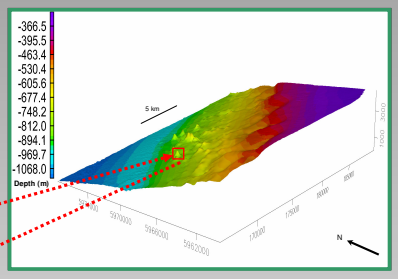


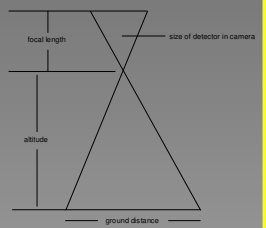
Fig.4. 3D shaded relief representation of processed *.xyz Irish National Seabed Survey (INSS) data with 45°illumination angle gridded at 60m cell size in GeoSoft Oasis Montaj.

ROV or towed vehicle array fitted with underwater camera

camera field of view

camera footprint on seafloor

Fig.1 Victor 6000 ROV (remotely operated vehicle) mounted with optical instrumentation showing data coverage obtained during video surveys. Size of the camera footprint increases if vehicle altitude is increased.



$$\frac{\text{altitude}}{\text{ground distance}} = \frac{\text{focal length}}{\text{size of detector}}$$

Fig.2 A camera's lens defines the focal length which relates to the footprint on the seafloor. As the focal length increases the field of view decreases. The two triangles are similar, therefore the ratios above are equal.

Seafloor Classification

The occurrence of cold-water corals have been recorded at a variety of locations along the Northeast Atlantic margin (e.g.Hovland, 2003; Kenyon, 2003). In particular coral thickets have been located on carbonate mound structures of the seabed in the Porcupine Bank, Seabight and Rockall Trough and Bank. The mounds themselves are unique topographic features found at depths of 600-1000m. A megahabitat (tens of kilometres and larger) according to the definition by Greene *et al.* (1999) was identified from geoacoustic (bathymetry and backscatter) data (Fig. 4) along the upper continental slope of the SE Rockall Trough, west of Ireland. Applying the Greene *et al.* 1999 classification, the key attributes for this example: continental slope megahabitat at 500m-1000m depth, hard substrate, carbonate, mound feature, bimodally mixed, and sloping with moderately complex seafloor. A classification code for use within a GIS (Geographic Information System) has been developed to describe large scale and small scale habitats. Assigning the code we describe the megahabitat as follows; **F h (h) m l 1 C.** The terms macro/microhabitat refer to seafloor features ranging in size from one to ten metres (Greene *et al.* 1999). Small scale macro/micro habitats are described in the images below.

Rippled sand

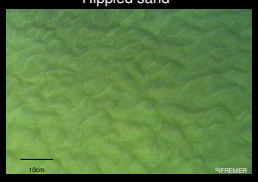


Fig.5 Image of sand ripples captured at 3.1m above the seafloor using a downward facing camera. Classification (Greene *et al.* 1999) : flat or nearly flat sand rippled (100%) bottom; moderate complexity. * (s) 1 C. The classification code for geologic attributes has been modified to include 'rippled sand', represented by subscript „.

Dropstone

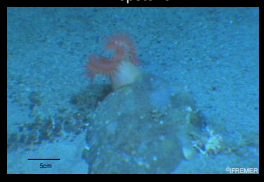


Fig. 6 Dropstones are a feature of off-mound flat seafloors between carbonate mounds. Classification as before: dropstone on sand/pebble seafloor with anenome.
Flat moderately complex Code: * (o) (p) (s) [n] 1 C The classification code does not classify for dropstones so has been modified to include 'dropstone' (o) as a geologic attribute.

Live coral

Fig. 7 Deep-water living corals thrive at the upper regions of mounds e.g. dense *Lophelia pertusa* have been recorded in underwater video from the top of mounds on the seafloor. Classification; Coral reef on flat seafloor with high complexity. * (h) [c_L] 1D. The classification code has been modified to specify coral that is living [c_l]

Coral debris

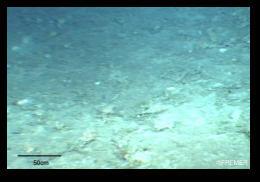


Fig. 8 Freiwald (2003) suggests in addition to thriving live coral, coral banks have a characteristic dead coral framework and debris zone, often clogged with sediment. Wheeler *et al.* (2003) refer to a sediment clogged dead coral/rubble seabed facies when classifying seafloor in the Porcupine Seabight, NE Atlantic. Classification; Carbonate, coral debris on flat seafloor with moderate complexity * (h) [c_d] 1 C The code is modified to include 'coral debris' [c_d] as a geologic attribute in classification scheme.

Semi-automated classification

Marine scientists spend many hours processing underwater video data. To address this problem, a set of algorithms designed to detect specific features of interest in mission videos is being developed at Heriot-Watt University. The approach is based on supervised image classification "large margin classifiers" (classifiers with good properties and performance) are applied to partition the image data into a number of classes, each pixel being attributed a label.

Using images of deep-water corals, the automated approach proposes to discriminate between the presence of coral and non-coral in an image to estimate coral density and this information can be georeferenced (Lebart, 2004). By doing so, the video is partitioned into segments where features of interest can be quickly selected and processed by the scientist.

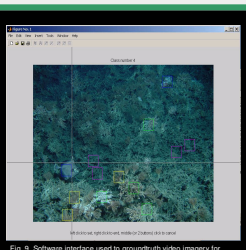


Fig. 9 Software interface used to groundtruth video imagery for semi-automated classification. Boxes or regions of interest (roi's) represent those feature classes of specific interest for training the algorithm.

Summary

•The Irish National Seabed Survey dataset will assist in identifying seafloor features of interest for detailed benthic habitat mapping using underwater video imagery.
•Various operational constraints exist during the collection of video data which affect the processing stage, these are to be considered when planning video surveys to ensure best possible resolution underwater imagery is obtained.
•The classification scheme proposed by (Greene *et al.* 1999) was applied to classify a large scale megahabitat in the SE Rockall Trough. This scheme though comprehensive required some additions to the geologic and biological attributes at the macro/microhabitat scale to be applicable to seafloor features presented in video imagery.
•Algorithms for the semi-automated classification of video currently in the development phase offer the potential of reducing the amount of operator time required for video analysis by identifying areas in the video which are of most interest to the scientist.

References

Freiwald, A., Reef forming cold-water corals *from* Wefer, G., Billett, D., Hebbeln, D., Jørgensen, B.B., SchlÜter, M., Van Weering, T. (eds) 2002, *Ocean Margin Systems*. Springer-Verlag Berlin Heidelberg, pp 365-385.
Greene, H.G., Yoklavich, M.M., Starr, R.M., O'Connell, V.M., Wakefield, W.W., Sullivan, D.E., McRea Jr., Caillet, G.M. A classification scheme for deep seafloor habitats. *Oceanologica Acta* **22** (6) pp 663-678.
Hovland, M., Risk, M., (2003) Do deep-water corals reefs rely on seeping fluids? *Marine Geology* **198** (1-2) pp 83-96.
Kenyon, N.H., Akhmetzhanov, A.M., Wheeler, Andrew J., Van Weering, T.C.E., de Haas, H., Ivanov, M.K. Giant carbonate mud mounds in the Southern Rockall Trough, *Marine Geology*, **195** (1-4) pp 5-30.
Lebart, K., Maudez, E., Cherif, I., Redpath, D., Smith, C., Grehan, A., (2004) Automated video analysis for trawling mark impact assessment and deep water coral environment monitoring. Oceanology, London.
Wheeler, A.J., Kozachenko, M., Beyer, A., Foubert, A., Huvenne, V.A.I., Klages, M., Masson, D.G., Olu-Le Roy, K., & Thiede, J. Sedimentary processes and carbonate mounds in the Belgica mound province, Porcupine Seabight, NE Atlantic. In: A. Freiwald & J.M. Roberts (eds). *Proceedings of the 2nd International Symposium on Deep-water corals*, Springer-verlag.

Acknowledements
This work is part funded by the National University of Ireland, Galway's Marine Science Research Project 3.2 under the Irish Higher Education Authority programme for research in Third Level Institutions, Cycle III and by the 5th Framework Access to Research Infrastructure project EIERO (European Infrastructure for Energy Reserve Optimisation). Support from the 5th Framework Program of research project AMASON (Advanced Mapping and Sonar) is also acknowledged. The authors would also like to thank the Geological Survey of Ireland (GSI) for use of the Irish National Seabed Survey dataset.