Use of automated image analysis to detect changes in megafaunal densities at HAUSGARTEN (79N west off Svalbard) between 2002 and 2004

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Introduction

- In 1999: Launch of the first and only deep-sea long-term observatory beyond the polar circle: HAUSGARTEN (eastern Fram Strait) \cite{1}
- Purpose: To achieve an understanding of the abundance and spatial distribution of organisms
- \textit{→} assess the effects of global change.
- Acquisition of a large quantity of underwater footage
  \textit{→} visual analysis is very labour-intensive and time-consuming.
- New approach: Application of machine learning algorithms for the automatic analysis of the HAUSGARTEN footage
- Main focus:
  \textit{→} The detection and classification of the most important biological species.
  \textit{→} The assessment of population abundances and variations.

Material

- Photographic transects from the HAUSGARTEN central station (2500m) (Figure 1)
- Taken by an ocean floor observation system (OFOS) associated to the research vessel Polarstern (Figure 2) in 2002 and 2004.
- Each transect contains some 700 photographs.
- RGB TIFF-Format, 3504 \times 2436 pixels.
- Most important species:
  \begin{itemize}
  \item sea cucumbers
  \item star fishes
  \item sea lilies
  \end{itemize}

Methods

Training

- Hand labelling of data
  \textit{→} determination of occurrence and position of species
- Subdividing images into smaller parts
- Generation of a training set with
  \textit{→} subimages containing a particular species
  \textit{→} subimages without this species
- Training of a classifier (Support Vector Machine) \cite{2}

Application

- Segmentation of interesting objects:
  \textit{→} different algorithms for different species
  \textit{→} Application of the classifier to the segmented object

Results

Evaluation procedure

- divide dataset into 5 subsets
- use 4 subsets for training, the remaining subset for testing
- five evaluation steps, each subset is used once as testing set \textit{→} Five Fold Cross Validation
- the classifier is tested with the training set and evaluated by classifying the images of the testing set

Evaluation measure

- During each evaluation step the several images are counted:
  \textitem{\textbf{→}} those classified correctly as a particular class member (true positive - TP)
  \textitem{\textbf{→}} those classified incorrectly as a particular class member (false positive - FP)
  \textitem{\textbf{→}} those classified incorrectly as not class member (false negatives - FN)
- Two measures are computed for describing the classification result \cite{3}
  \textitem{\textbf{→}} The Sensitivity (SE) measures the amount of correctly classified class members within all class members:
  \[ SE = \frac{TP}{TP+FN} \]
  \textitem{\textbf{→}} The Positive Predictive Value (PPV) measures the amount of correctly classified class members within all objects classified as a class member
  \[ PPV = \frac{TP}{TP+FP} \]

Optimised parameter settings of the particular system lead to promising results of the system performance. The following SE and PPV values for the different species could be achieved.

<table>
<thead>
<tr>
<th>Species</th>
<th>SE</th>
<th>PPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea cucumbers</td>
<td>85.64%</td>
<td>78.21%</td>
</tr>
<tr>
<td>Star fishes</td>
<td>74.47%</td>
<td>74.57%</td>
</tr>
<tr>
<td>Sea lilies</td>
<td>66.14%</td>
<td>55.45%</td>
</tr>
</tbody>
</table>

\textitem{\textbf{→}} Satisfying results for star fish and sea cucumbers
\textitem{\textbf{→}} Detection of sea lilies still requires improvement

Conclusion and Outlook

- We have proven the general feasibility of our approach for the detection of species
- Two particular species can already be detected and identified reliably
- Results from manual analysis of 66 images taken at the central part of the transect:
  \textitem{\textbf{→}} significant decline in mean density of sea cucumbers (Elpidia glacialis), sea lilies (Bathycriinus cf. carpentieri), burrow entrances and total megafaunal densities from 2002 to 2004.
  \textitem{\textbf{→}} This concurs with a decrease in sea ice coverage, particulate flux to the sea floor, sediment-bound nutrients and pigments, microbial biomass and changes in meiofaunal community structure.
- \textitem{\textbf{→}} Results from automated image analysis will increase the spatial resolution and statistical power of our analysis
  \textitem{\textbf{→}} processing of larger quantities of images.

References


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