Vision-based Real-time Zooplankton Detection and Classification using Faster R-CNN

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Abstract

Zooplankton is a key ecological component of aquatic ecosystems. Studying and monitoring the spatial distribution and temporal variability of zooplankton is vital to understanding their community composition and its relation to climate change. Manual methods for analysis are time-consuming and have limitations on the ecological studies of these organisms. Real-time, fast and accurate in situ zooplankton detection and classification remains a challenge. Currently, research focuses on automating zooplankton image classification using handcrafted computer vision techniques and neural network based approaches [1,2]. Most recent approaches adopt deep learning techniques for identification and classification [3,4]. In this paper, we propose the use of Fast Region-based Convolutional Neural Network (Faster R-CNN) for fast and accurate in situ detection and classification of zooplankton groups in underwater images. Faster R-CNN is a region-based object detection framework which combines region proposal and classification in a unified network [5]. Indeed, end-to-end learning reduces overall training time and increases the accuracy of the network. Faster R-CNN has shown state-of-the-art performance on benchmarks such as ImageNet and VOC [6,7]. We perform the experiments over ZooScan, Kaggle, WHOI-Plankton datasets [8,9,10]. We evaluate the performance of our proposed approach of in situ zooplankton identification and classification in terms of detection speed and mean Average Precision (mAP). In addition, we compare the performance of the proposed method with popular detectors such as Single Shot Multibox Detector (SSD) and You Only Look Once (YOLOv3) to demonstrate its efficacy at processing noisy underwater images [11,12]. Results of our evaluation recommend the use of Faster R-CNN for real-time zooplankton image analysis. The ultimate goal of this work is to automate the current manual process exerted in the lab while improving the accuracy and processing speed of an otherwise time-consuming task for marine biologists.

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Introduction

We propose the use of Faster Region-based Convolutional Neural Network (Faster R-CNN) for fast and accurate detection and classification of zooplankton groups in underwater images.

Faster R-CNN is a region-based object detection framework which combines region proposal and classification in a unified network [1]. End-to-end learning reduces overall training time and increases the accuracy of the network.

We also compare the performance of the proposed method with popular detectors like Single Shot Multibox Detector (SSD) [2] and You Only Look Once (YOLOv3) [3].

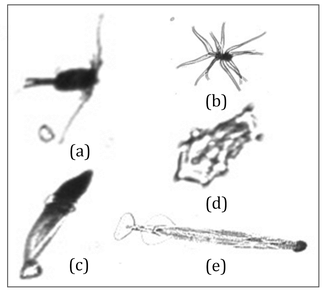


Fig 1. Zooplankton Groups from the Kaggle dataset [4]: (a) Copepod, (b) Echinoderm, (c) Fish larva, (d) Siphonophora, and (e) Chaetognatha

Motivation and Goals

- **Automate lab-based manual methods of zooplankton detection and classification.**
- **Reduce overall training time through end-to-end learning**
- **Improve the neural network detection and classification accuracy**

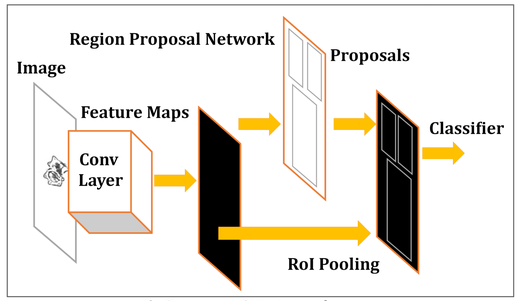
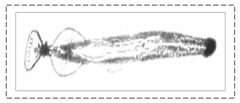


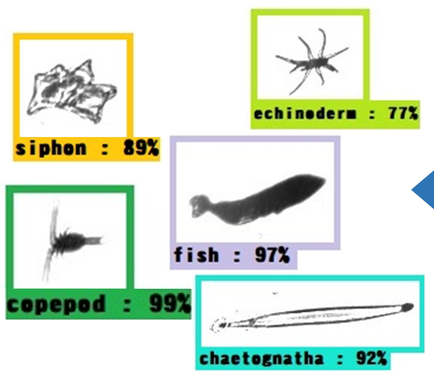
Fig 2. Faster R-CNN Network

Image Pre-processing: 10px padding added on all sides to increase the image background size



Preparing dataset and generating supporting file formats for Faster R-CNN, SSD, YOLO

Original image files	XML files for images with bounding boxes	Text files
1210.jpg	1210.xml	1210.txt
1613.jpg	1613.xml	1613.txt
...	...	...
...	...	...
3116.jpg	3116.xml	3116.txt



Detection and Classification (Network Training – Faster R-CNN, SSD, YOLO)

Evaluation

Mean Average Precision (mAP) is a popular metric for the evaluation of object detectors like Faster RCNN, SSD, YOLO.
Average Precision, AP for class c:

$$AP = \frac{\#TP\ (c)}{\#TP(c) + \#FP(c)}$$

True Positive, TP(c): when a proposal is made for an object of class c and the object is present
False Positive, FP(c): when a proposal is made for an object of class c, but there is no object of class c
Mean Average Precision, mAP for class c:

$$mAP = \frac{1}{|classes|} \sum_{c \in classes} \frac{\#TP(c)}{\#TP(c) + \#FP(c)}$$

Intersection over Union, IoU:

$$IoU = \frac{A \cap B}{A \cup B}$$

Set A is proposed object pixels and set B is true object pixels

Algorithm	mAP@0.5IoU
Faster R-CNN	97%
SSD	84%
YOLO	79%

Table 1. mAP scores for Faster R-CNN, SSD, YOLO

Conclusion

Faster R-CNN proved to be most efficient at processing the images of zooplankton with a high mAP score. More images in the dataset and more training time would result in a much better performance.

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