SCOR proposal for a working group on

Automatic Visual Plankton Identification

Background and Rationale

One of the main problems confronting plankton research is low sampling resolution, both spatial and temporal. Although it is widely recognized that the relevant scales for plankton are much smaller than those usually sampled, the work involved in plankton sample analysis has made it impossible to sample at very high resolution in most programs. To some extent the lack of sampling capability has been resolved using simplified measurements such as Chl a, total biovolume, biomass (wet or dry weight) or more sophisticated systems providing size and number of particles (e.g. OPC). However, these methods lack the ability to distinguish between different functional groups of plankton known to have very different roles in the ecosystem (e.g. diatoms vs flagellates, marine snow, or copepods vs appendicularians).

In recent years several *in situ* and laboratory imaging systems have been developed. These systems are capable of obtaining relatively good-resolution images at high sampling rates that would, in theory, allow quantification of the abundance of taxonomically well-resolved groups in the appropriate spatial and temporal scales (Wiebe & Benfield 2003). Development of these systems has presented a new problem: the manual analysis of images from such systems is impractical; due to the huge amount of information and quantities of images they produce. New image analysis systems offer a potentially advantageous solution compared to manual methods of counting and sizing. With the aid of image analysis and classification software and hardware, the images can be identified to at least major groups. Many sophisticated automatic recognition algorithms exist, and research in this area is very active. There is a very real potential of using image analysis techniques to obtain more refined taxonomic classification in the near term.

In the future, if marine science is to achieve any progress in addressing biological diversity of plankton in the ocean then it needs to sponsor development of new technology to image and identify specimens in plankton samples, acting as an adjunct to existing (and increasingly scarce) taxonomists and marine ecologists (Culverhouse et al. 2006). We propose to focus on the automation of identification. Drawing from recent progress in object recognition in the wider machine vision community marine scientists and engineers have had some significant successes in demonstrating automated recognition of plankton taxa.

A training set of objects is used to establish the pool of features and their prior distributions. Statistical and other pattern classification methods are then used to cluster the feature occurrences in test specimens and hence derive identification. Thus, in the Automatic Diatom Identification and Classification (ADIAC) system (DuBuf and Bayer, 2000) a large set of morphological measurements (for example, specimen length, width, aspect ratio) is made of each specimen placed under the microscope. Some of these measurements are similar to those made by taxonomic experts and is similar to ZooSCAN (Grosjean et al., 2004), used for zooplankton recognition and counting where a “forest” of classifiers is used. DiCANN (Dinoflagellate Identification by Artificial Neural Network; Culverhouse et al., 1996), a tool for dinoflagellate phytoplankton species recognition, analyses low-resolution shape, texture, and size characteristics, but uses the machine to discover how these features correlate with object classes through Support Vector Machine (SVM) clustering. Recently SIPPER (Shadow Image Particle Profiling Evaluation Recorder; Samson et al., 2001; Remsen et al. 2004) has employed SVM categorisers fed from shape moments, granulometric and domain-specific features to recognise five classes of plankton. The Video Plankton Recorder (VPR), developed at Woods Hole Oceanographic Institution, has been used as a test bed for a number of analysis protocols (Tang et al., 1998; Hu and Davis, 2005). The most recent VPR system demonstrated recognition through texture analysis and categorisation.

Using automation to assist experts in visual plankton identification is relatively new. Engineers and scientists developing these instruments usually assess machine performance through cycles of training and testing. Most systems in development at the moment rely on images of plankton collected from the field or from culture samples. The experimenter labels each specimen image, which is then processed by the machine. The machine-given label is then compared to the human-given label to assess machine performance. Once performance is at an acceptable level the machine is ‘released’ for more routine application. An important step in the evaluation, and subsequent widespread scientific use, of these identification machines is the validation of their labelling abilities. It must also be recognised that people are biased and can make mistakes whilst labelling specimens. These errors must be removed from reference data sets used for training machines (Culverhouse et al 2003). A factor governing the widespread adoption of these new machines is the level of confidence the community has in their performance, and the quality of their results. Existing manual methods are, in a sense, rigorously quality controlled. The same must be established for automatic methods.

A recent GLOBEC/SPACC-sponsored workshop held at San Sebastian, Spain, in November 2005, concluded that it was imperative to co-operate and not compete in the development of machine vision solutions for automatic labelling of plankton. The RAPID (Research into Automatic Plankton Identification) group arose from this, formed initially by members of the workshop. This group is ideally placed to support the development of standards and foster the spirit of co-operation. A team from the organising members of RAPID has liaised with SCOR WG115 on Standards for the Survey and Analysis of Plankton and produced this proposal for a new working group.

GLOBEC, IMBER, Census of Marine Life, and Census of Marine Zooplankton are some of the global initiatives that will benefit from the outputs of this working group. This is reason enough for an international approach to this work. However it is also important from several other perspectives: plankton identification is an international problem, and a global approach will increase the visibility of local solutions to identification and perhaps also adoption of solutions from outside marine science. A common platform will make it quicker to integrate new software into applications that are immediately useable by marine scientists.

<u>Relevance to Other SCOR Activities</u>

This working group would be highly relevant to the future of the Continuous Plankton Recorder (CPR) and other time series biological surveys as significant increases in throughput could be achieved by automation supporting manual analysis of samples. Automatic identification of common taxa will free taxonomists to focus on the more difficult identifications and deeper questions. This could also encourage ‘new blood’ into taxonomy and systematics.

The outcome of the proposed group could make collection of future data for worldwide comparisons of zooplankton populations easier (WG 125), The proposed group will consult regularly with the SCOR Panel for New Technologies for Observing Marine Life (two associate members of the proposed WG are members of the Panel—Gaby Gorsky and Sun Song), particularly on collaborative workshops.

An order of magnitude increase in existing analysis throughput is required to address the needs of global monitoring and research programmes such as GOOS, GLOBEC, and IMBER. Automation will help achieve this increase and the new working group would assist through the following terms of reference.

Terms of Reference

The RAPID group have identified an urgent need for a common software toolbox for plankton image classification, which is robust and flexible, allows data post-processing for ecology modelling and other applications and is fast for *in situ* real-time processing. It is accepted that open source software, supported by a community, is a reliable way of generating robust code that is tailored to the needs of the community. These terms of reference are designed to foster and grow that community for automated visual identification of marine plankton, together with reviewing practices and establishing the necessary standards to ensure widespread uptake of these new technologies across biological oceanography. The working group will attempt to foster a confidence in marine scientists, who may feel threatened by the adoption of this technology. It will define standards for image data validation for use in training machines and people.

The proposed terms of reference are

- *To encourage the international co-operation of software developers and marine scientists to use and enhance the open-source development platform, so that a common toolset can be built up over time that is of value to the community.*

Rationale: the RAPID community, as the basis of its toolset, has adopted the Zooimage common software platform. To be of value to the wider scientific community, this open-source toolset needs strong support from a critical mass of end-users and developers. This SCOR Working Group could achieve support through both dissemination activities and through the review of function and leading the debate of developer and end-user issues. The opportunity of an open source platform for specimen identification is extremely important, as it gives all developers and users an easy way of extending and enhancing function with a low cost of effort. This is particularly important in developing nations where large repositories of taxonomic expertise exist but financial resources for acquisition of commercial software and hardware are frequently limiting. This activity will best be addressed through a working group meeting to discuss dissemination and then through the Internet and academic/conference papers.

- *To review existing practices and establish standards in the use of reference image data used for training automation machines and in training people.*

  Rationale: A global database of specimens and images is needed for training machines and also for training experts. A pilot web site to address this aim is being set up at both Plymouth University and Louisiana State University. However, the exact nature and function of the database should be defined by the biodiversity, ecology and taxonomy communities as well as the software developers. This working group would be well placed to stimulate discussion and establish international operational standards for the reference system, through the Internet, working group meetings and academic/conference papers.

- *To establish a methodology for inter-comparison/calibration of different visual analysis systems*.

  Rationale: wide availability of computer-based plankton recognition systems will cause difficulty for potential customers, as systems performances are compared. A common set of benchmark measurements will simplify the comparisons and strengthen both the developer community and the end-user confidence in these systems. Such benchmarks are commonplace in the computing industry. They need to be created for this new domain.

- *Encourage the adoption of the open-source ZOOIMAGE to the marine ecology, taxonomy and systems developers. Publish the products of reviews by members of the Working Group, selected presented papers and workshop reports in an internationally recognised, peer-reviewed journal or a book by a major publisher.*

  The proposed working group will extend the dissemination activities to special sessions at existing international conferences, to raise the profile of progress and solutions. Funding for these activities will be sought from other agencies and foundations.

Sponsorship by SCOR would focus the international community on the working group's terms of reference, which will facilitate global debate and hopefully mark rapid progress in automatic plankton identification.

Working Group Composition (with plankton recognition systems in [...])

The working group will have two co-chairs, Mark Benfield (USA) and Phil Culverhouse (UK). Benfield is a marine scientist, but has worked on plankton recognition software for some years. Culverhouse is an electronics engineer with a background in biology and experimental psychology; he has been developing plankton identification techniques since 1989.

Full Members

Elena Arashkevich (Russia)	Zooplankton taxonomist
Mark Benfield (USA)	Zooplankton ecologist and machine vision software developer/user [VPR, ZOOVIS] **and co-chair of group**
Phil Culverhouse (UK)	Cognition, AI and machine vision engineer [HAB Buoy] **and co-chair of group**
Philippe Grosjean (Belguim)	Statistician and machine vision software engineer [Zooimage]
Maria Grazia Mazzocchi (Italy)	Zooplankton Taxonomist

Rubens Lopes (Brasil)	Zooplankton ecologist and machine vision user [Zooscan]
Angel Lopez-Urrutia (Spain)	Zooplankton ecologist and machine vision software developer [R-package]
Josué Alvarez-Borrego (Mexico)	Phytoplankton ecologist and machine vision developer
Mike Sieracki (USA)	Phytoplankton ecologist and machine vision software user [Flowcam]
Hans Verheye (South Africa)	Zooplankton taxonomist

Associate Members

Hans DuBuf (Portugal)	Engineer and machine vision developer for Diatom ecology [ADIAC]
Gaby Gorsky (France)	Zooplankton ecologist and machine vision software developer/user [Zooscan, UVP]
Carin Ashjian (USA)	Zooplankton ecologist and machine vision software developer/user [VPR]
Xabier Irigoien (Spain)	Zooplankton ecologist and machine vision software user
Sun Sung (China)	Zooplankton ecologist and machine vision software developer/user
Bob Williams (UK)	Zooplankton ecologist and machine vision software developer/user [HAB Buoy]
Norm McLeod (UK)	Morphometrician morphometrics method developer, micropalaeontologist, with interest in machine vision software; also, as Keeper of Palaeontology at Natural History Museum, user/ link to terrestrial and paleontological systematics groups

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