Fast recognition of marine particles in underwater digital holography

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Fast recognition of marine particles in underwater digital holography

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ABSTRACT

The issue of fast recognition of marine particles *in situ* by digital holography methods is considered. An algorithm for the classification of marine particles by morphological features is proposed. Preliminary results and estimation of accuracy of the proposed algorithm are presented.

Key words: digital holography, plankton, recognition, classification, taxonomic features, image processing.

1. INTRODUCTION

Information about the species composition of plankton is of great practical importance in the tasks of monitoring and research of aquatic ecosystems. Plankton can be considered as the bioindicator of the aquatic environment. By the presence of certain types of organisms in the water, it is possible to assess the degree of water pollution or eutrophication [1]. The study of the plankton species in the tasks of hydrobiology and ecological monitoring needs the solution of the problems connected with their recognition within the framework of the basic taxonomic groups [2].

The classifying of marine particles with the use of optical or holographic methods can be divided into three stages:

1) direct registration of the particles by optical system (e.g. microscope) or reconstructing images of marine particles from the hologram in digital form or digitizing them (in the laboratory or *in situ*);

2) the choice of the classification algorithm and taxonomic features;

3) the particle images processing with subsequent recognition and/or classification by software.

Digital holography methods allow obtaining images of the investigated volume with marine particles in real time *in situ.* One digital hologram contains information about all the recorded volume with particles and allows examination of each particle, that is not provided by other methods [3]. Therefore, the study of plankton particles using digital holography is most informative.

Currently, there are many standard software that implement both an algorithm for reconstructing images of particles from a digital hologram and image processing methods [4, 5]. This cannot be said about the choice and determination the taxonomic features. Planktonic particles are difficult objects for selection in the holographic image of volume, their recognition and classification [6-8], especially in conditions of obtaining information in real time. Therefore, the reliability of recognition of marine particles in their habitat is determined by the correct choice of the classification algorithm and taxonomic features that are adequate to the problem being solved.

2. ALGORITHM DESCRIPTION

In this paper we propose a software algorithm for the classification of plankton particles, presented in the form of a block diagram in Figure 1. First, the image reconstruction is realized of volume sections containing particles, determination of the transverse coordinates of the particles, and further more accurate reconstruction of the focused (sharp) images of particles and determination of their longitudinal coordinates as the best focusing plane by the use, for example, the Tenengrade method [9, 10]. Then the focused images of particles are combined in the one plane, taking into account their transverse coordinate and the magnification of the optical system for the consequent longitudinal coordinate. Composing this way image will be called two-dimensional (2D) or integral representation [9, 10]. At the next stage, binarization and selection each the particle image in the 2D representation is arranged. The global threshold for binarization is calculated automatically. The choice of threshold is based on the analysis of the histogram of the 2D representation with particles. After binarization the measurement of each particle characteristic sizes is to be done for the morphological parameter calculation. The ratio of the minimum and maximum sizes of the rectangle circumscribed around the particle is suggested to be used as a morphological parameter. This morphological parameter allows separating the particles into

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taxons at the next stage. To automatically classify marine particles, it is necessary to carry out the classifier training (the decision tree is used as the classification algorithm). It is possible to determine the optimal morphological parameter values for each taxon according to the training set of data (sample), i.e. by known sea particles.

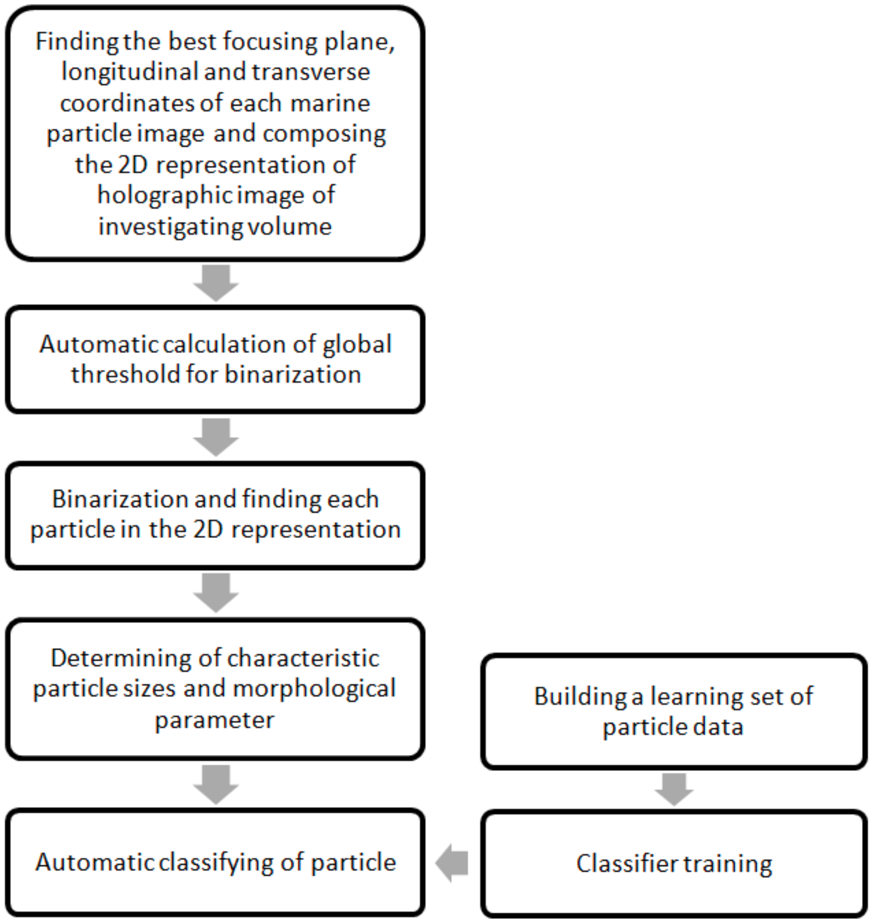

Figure 1 – Block diagram of the algorithm for classifying marine particles images reconstructed from digital hologram

The morphological parameter of a particle proposed in this work as a taxonomic classification feature allows separating zooplankton by orders. To classify by lower rank (family, genus or species), additional taxonomic feature such as particle size, antennas presence, boundary contrast, and others should be used, that will increase processing time. Since the classification by lower rank require significantly more processing time, so it makes sense to do this through subsequent laboratory processing of files (usually with the operator) collected under expeditionary conditions. For the purposes of fast research, we shall limit with one taxonomic feature – the morphological parameter described above – and determine the accuracy of classification with this parameter.

3. RESULTS AND DISCUSSION

The training sample for classification is made up of planktonic images, presented in marine species identification databases [11-13]. Figure 2 shows some of the used images of plankton particles on which the rectangles circumscribed around the particles are marked. The choice of representatives of taxon is based on the final report of the annual environmental monitoring in the area nearby the Prirazlomnaya OIRFP made in 2012 year [14].

A preliminary estimation of the distribution of plankton particles by morphological parameters is shown in Figure 3. The "other" includes: jellyfish, mollusks, meroplankton and phytoplankton. The accuracy of the classification (the part of correctly classified particles among the total number of particles) for a given sample is 69.57%. Low accuracy is caused by the fact that morphological parameters of Rotifera species are uniformly distributed in three intervals from 0.27 to 0.87. To increase the accuracy in this case, it is necessary to introduce an additional taxonomic feature – the size of the plankton particle (the sizes of Rotifera species in this sample did not exceed 250 μm, the species size of other taxons is more than 250 μm). Then the classification accuracy is increased to 83.69%. The time taken to process this training sample was 3.5 seconds.

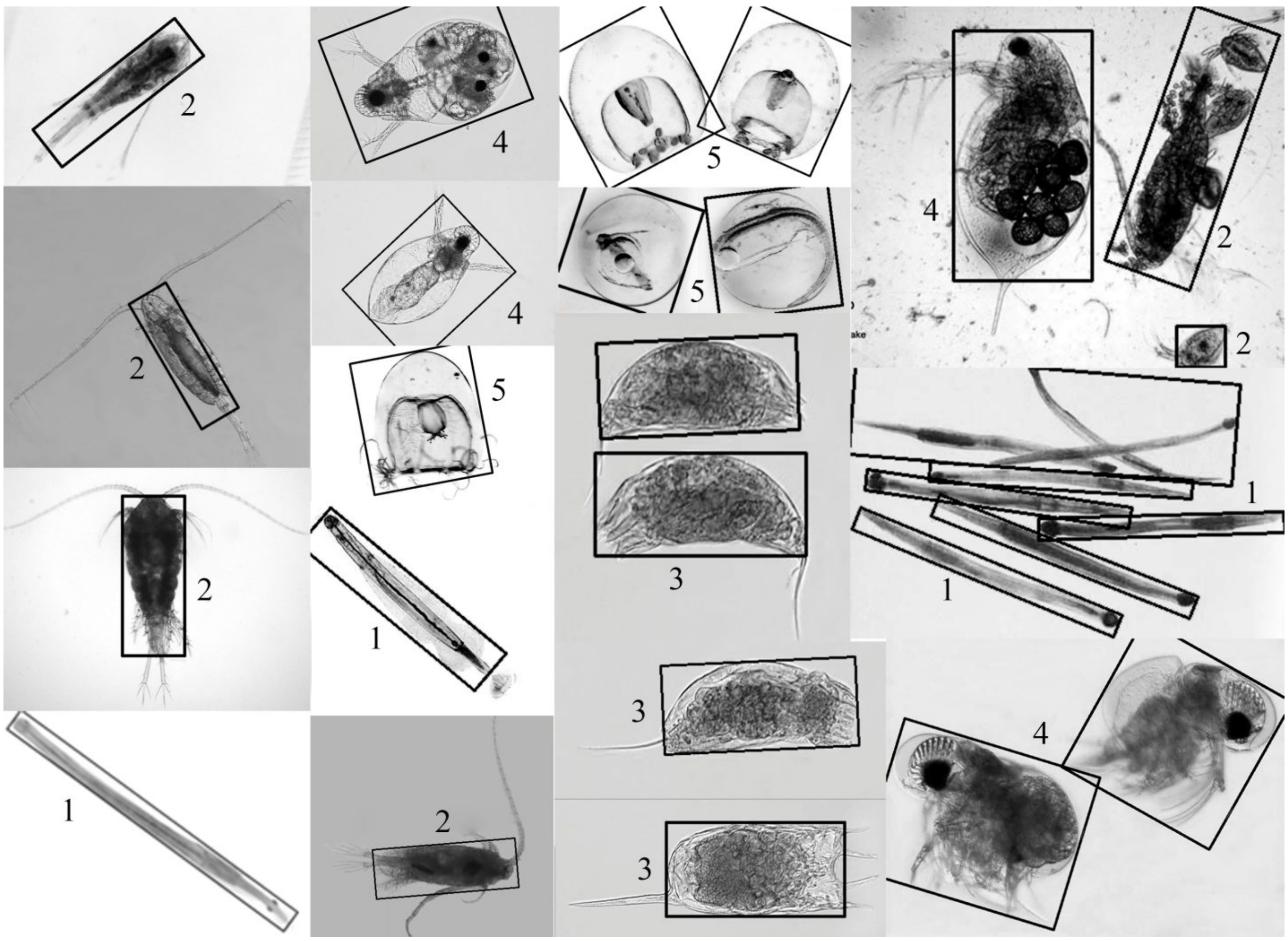

Figure 2 – Images of plankton particles [11-13] with rectangle circumscribed around the planktonic particle: 1 – Chaetognatha, 2 – Copepoda, 3 – Rotifera, 4 – Cladocera, 5 – Other (Hydrozoa and eggs)

The classifier built on the described above training set of plankton images was tested on a two images: 1) 2D image representation, reconstructed from a digital hologram of volume with *Epischura Baicalensis* species (nauplius and adult stages) presented on Figure 4; 2) reconstructed image from digital hologram of volume with *Daphnia* sp. presented in Figure 5. Image processing (without taking into account the compilation time of the 2D presentation) depends on particle image quantity and was about 0.5 seconds for 30 particles detected in Figure 4 and about 0.2 seconds for 8 detected particles in Figure 5. The accuracy of the classification is 0.56 for image with *Epishura Baikalensis* sp. (17 of the 30 particles was correctly identifying, colored in blue rectangle in Figure 4) and 0.63 for image with *Daphnia* sp. (5 of the 8 particles was correctly identifying, colored in green rectangle in Figure 5). One of the factors that reduce the accuracy of classification is moving and rotation of particle, so minimum and maximum sizes of the rectangle circumscribed around rotated particle would be differ from real and morphological parameter would indicate the wrong taxon.

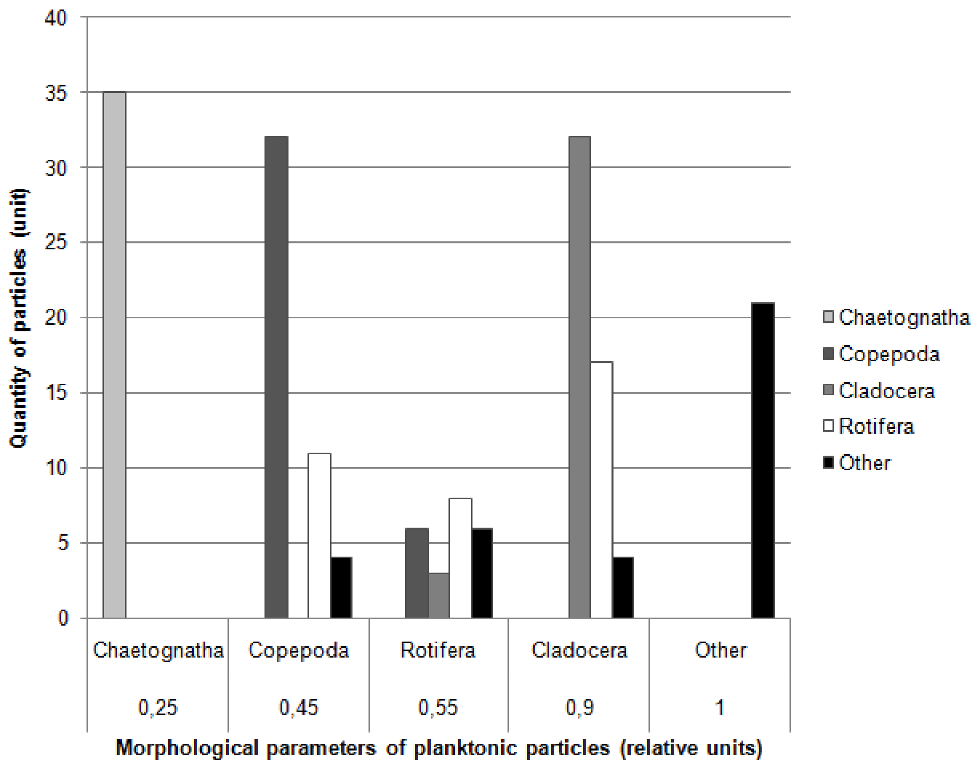

Figure 3 – Distribution histogram according to the morphological parameters of planktonic particles for various taxons

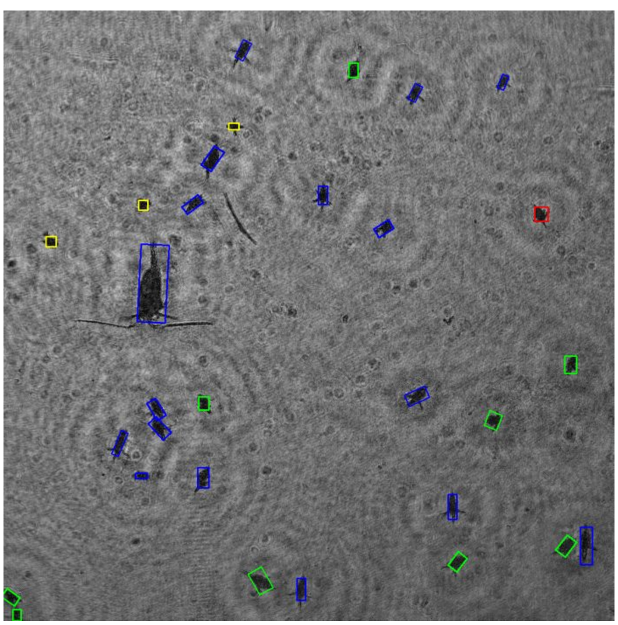

Figure 4 –The 2D representation of holographic image of investigating volume with *Epishura Baikalensis* sp. The color of the rectangle circumscribed around the planktonic particle indicate the taxon (result of classification): blue – Copepoda, yellow – Rotifera, green – Cladocera, red – Other

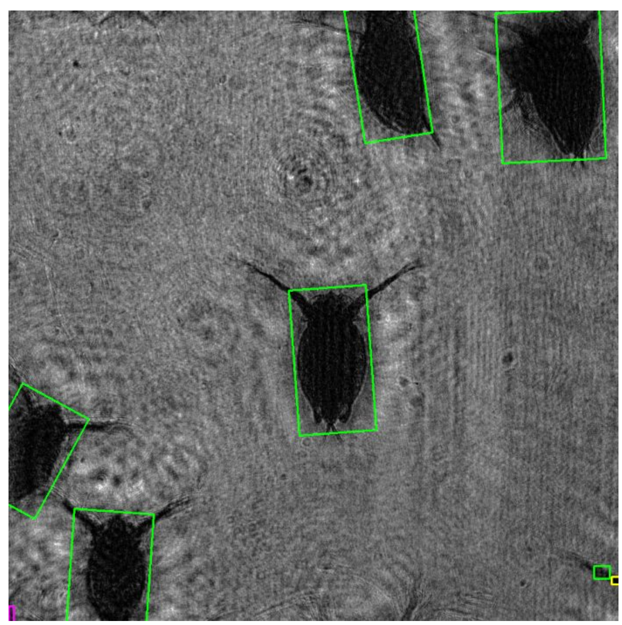

Figure 5 – Reconstructed image from digital hologram of investigating volume with *Daphnia* sp. The color of the rectangle circumscribed around the planktonic particle indicate the taxon (result of classification): magenta – Chaetognatha, yellow – Rotifera, green – Cladocera

The associated error will always be present in this algorithm in case of investigation moving plankton in volume, to reduce it, a training set containing images of plankton particles with different orientation is necessary.

Another factor that reduces accuracy is the loss of part of the plankton particle image at the edge of image (the lower left corner on Figure 4 and several particles in Figure 5). Such particles can be removed from consideration. And the last one error is associated with overlapping of particles images like on the top right corner in Figure 5. In this case, although the classifier correctly identified the particle, the second particle behind was not taken into account.

4. CONCLUSION

In this paper, we propose an algorithm and morphological parameter of particle as taxonomic feature for the rapid classification of plankton particles. The presented example gives grounds to believe that the classification of plankton particles by the morphological parameter allows a fairly reliable classification of plankton particles by orders in real time *in situ*.

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