Learning highly distinctive holographic features boosts micro-plastics recognition in water samples

Vittorio Bianco[1*], Pasquale Memmolo[1], Pierluigi Carcagnì[2], Francesco Merola[1], Melania Paturzo[1], Cosimo Distante[2], and Pietro Ferraro[1]

[1]*National Research Council (CNR) of Italy, Institute of Applied Sciences and Intelligent Systems (ISASI), Via Campi Flegrei 34, 80078 Pozzuoli (NA), Italy.*

[2]*National Research Council (CNR) of Italy, Institute of Applied Sciences and Intelligent Systems (ISASI), Via Monteorni snc University Campus, 73100 Lecce, Italy.*

**vittorio.bianco@cnr.it*

Here we combine Digital Holography microscopy with machine learning to identify with high accuracy microplastics within heterogeneous water samples. Highly distinctive coherent features are found to define a fingerprint for plastic items.

Keywords: Plastic pollution; Digital Holography;

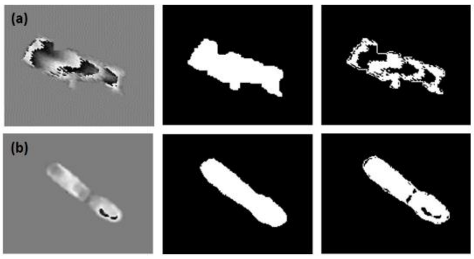
1. Introduction

Microplastics are one of the most alarming environmental concerns due to their potential impact on seafood, water pollution, and human health [1]. In order to detect the presence of microplastic pollutants in marine water, filtering and/or sieving procedures are performed to obtain samples falling within the desired range of sizes. However, a screening is required to identify plastic material from the other components of a pre-treated water sample. Unfortunately, the sole method currently adopted to assess the presence of microplastic items inside a liquid sample is a very cumbersome and time-consuming process made by unaided eyes at the optical microscope. Moreover, such analysis is low-throughput and very subjective, since it depends strictly from the operator experience and skills.

Here we introduce a novel approach that combines coherent label-free microscopy, namely Digital Holography (DH), with machine learning to achieve automatic and accurate recognition of microplastics in pre-filtered water samples over a wide range of scales [2,3]. In particular, a DH dataset is used to extract a set of features that can identify specifically a wide class of microplastic items that include different plastic materials of various morphologies, and sizes spanning in the range 10µm-1mm [3]. Thanks to this unique fingerprint, microplastics can be distinguished from marine diatoms, the most abundant microorganism that could be confused with microplastics in the sub-millimetre range into a marine water sample. The method we propose is high-throughput and can be thought as a block to be introduced in the existing water analysis chain to make a significant step forward in automatizing and accelerating the plastic screening process [2]. After this screening, low-throughput techniques like, e.g. FTIR can be used on the subset of elements identified as plastics to assess the specific material composition.

2. Results and discussion

We acquired and reconstructed holograms of microplastics spanning in the range 10µm-1mm. Within this range, we identified 9 populations of marine microalgae that could be easily confused with microplastics since these show similar morphology and characteristic sizes [3]. Thus, any classification approach based on the sole morphological and texture operators would fail in distinguishing between diatoms and plastics [4]. Figure 1(a-b) respectively show the phase-contrast map of (a) a microplastic and (b) a diatom. It is apparent that morphological operators cannot discern them with sufficient accuracy. Instead, the new descriptors based on the phase contrast map allow measuring the irregularities typical of microplastic items [3]. We classified 10000 objects belonging to 10 classes, i.e. the microplastic class and 9 classes of diatoms. We measured the performance of a SVM classifier receiving the both the classical and the holographic features [4]. The results of the K-folding test are shown in Fig. 1(c). We reached accuracy higher than 99% and the new features improved the performance of the classifier, thus demonstrating the effectiveness of the proposed approach [3].



(c)

	K=5	K=10	K=20
Accuracy [%]	99.13 ± 0.23	99.26 ± 0.20	99.31 ± 0.19
	87.23 ± 0.58	87.70 ± 0.61	87.88 ± 0.62
Precision [%]	98.36 ± 0.69	98.84 ± 0.51	99.10 ± 0.41
	60.07 ± 0.58	60.82 ± 0.46	61.16 ± 0.41
Sensitivity [%]	95.70 ± 0.86	96.40 ± 0.64	96.72 ± 0.47
	90.78 ± 0.64	91.01 ± 0.52	91.16 ± 0.43
Specificity [%]	99.82 ± 0.08	99.87 ± 0.05	99.90 ± 0.04
	93.29 ± 0.14	93.49 ± 0.11	93.57 ± 0.10
F1 Score [%]	97.01 ± 0.56	97.61 ± 0.41	97.89 ± 0.32
	72.30 ± 0.47	72.92 ± 0.38	73.21 ± 0.33

Holographic features   Classical features

Fig. 1 Classification performance. (a) Microplastic item. (b) Marine diatom. (c) Classification results (k-folding test) [3].

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