Evaluating Unsupervised Methods to Size and Classify Suspended Particles Using Digital Holography

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Holography can provide reliable estimates of particle size & concentration

- By providing in-focus images of suspended marine particles, digital in-line holography has become a valuable tool in many areas of marine research.
- However, estimating particle size distributions and concentrations using holography is computationally demanding compared to traditional techniques based on optics and acoustics.
- We have developed methods for the automatic identification, focusing, segmentation, classification and sizing of particles in holograms
- These have been evaluated using data collected from a variety of holographic systems, and from a significant range of particle types, sizes and shapes.

It allows in-focus imaging of particles throughout a volume

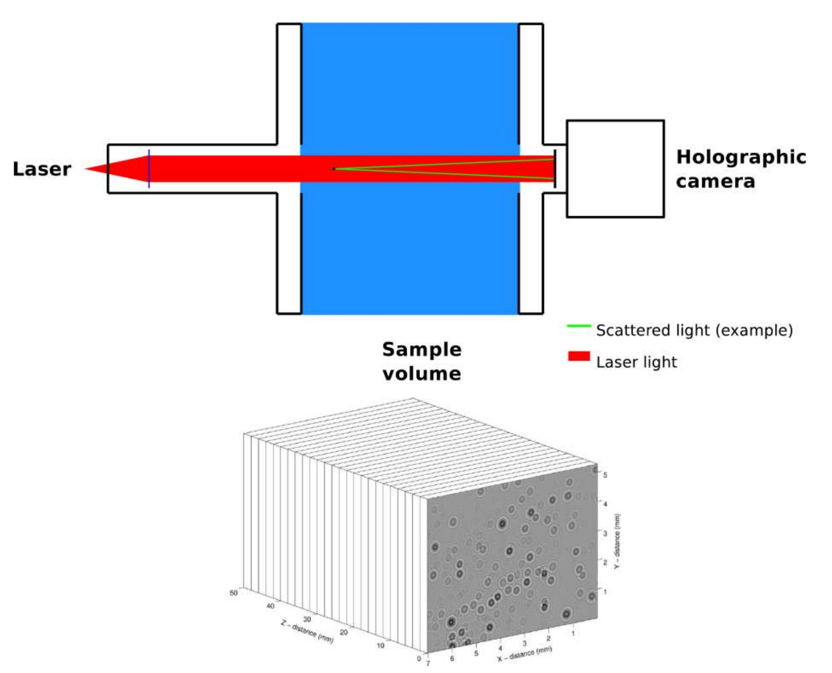


Figure: Scattering of laser light interferes with the incident light, creating an interference pattern.

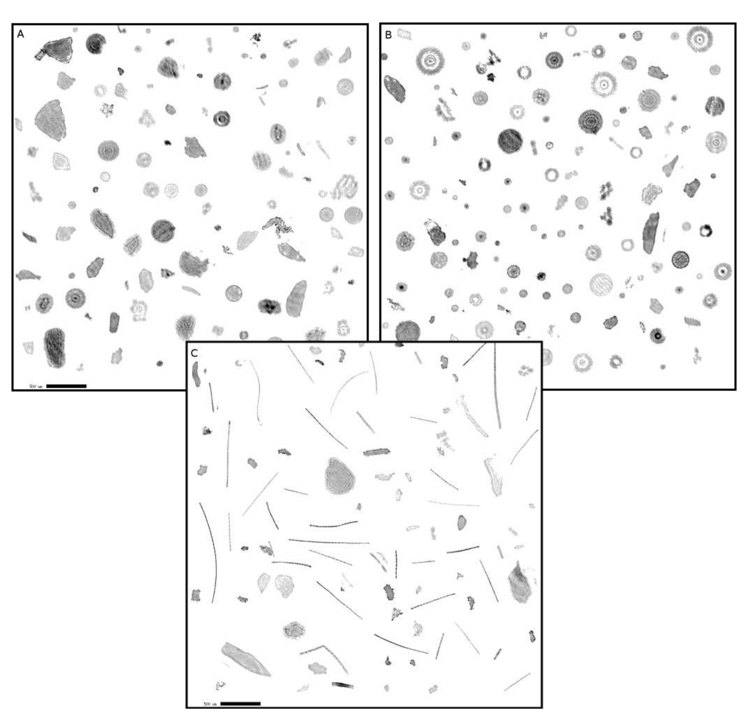


Figure: Auto-generated montages from bursts collected in the surf zone. A, B, and C are characterized by sand particles, bubbles and diatoms, respectively.

Design is flexible, & now there is a commericial system (LISST-HOLO)

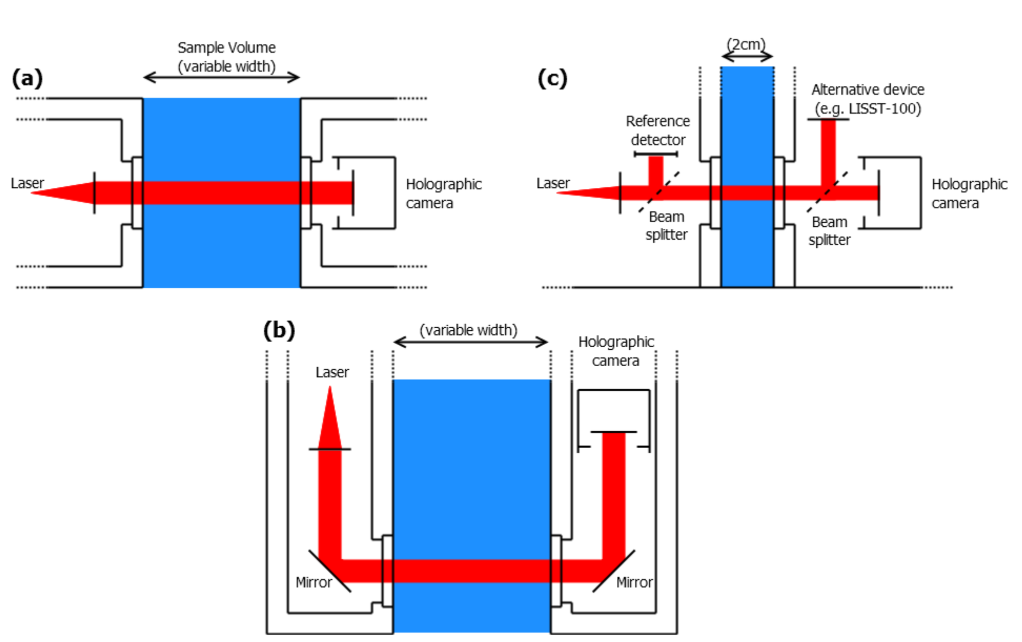


Figure: (a) Nose-to-nose, (b) Streamlined / profiling, and (c) Combined systems.

Figure: Streamlined design made at Plymouth University, deployed next to a nose-to-nose LISST-HOLO (Sequoia Scientific)

Holograms are numerically reconstructed & particles identified

Noise Removal in Raw Holograms Significantly Aids Particle Detection

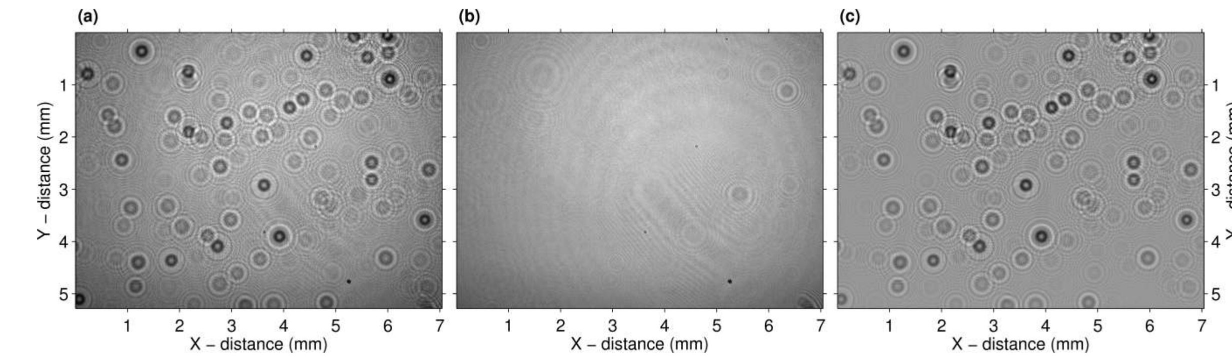
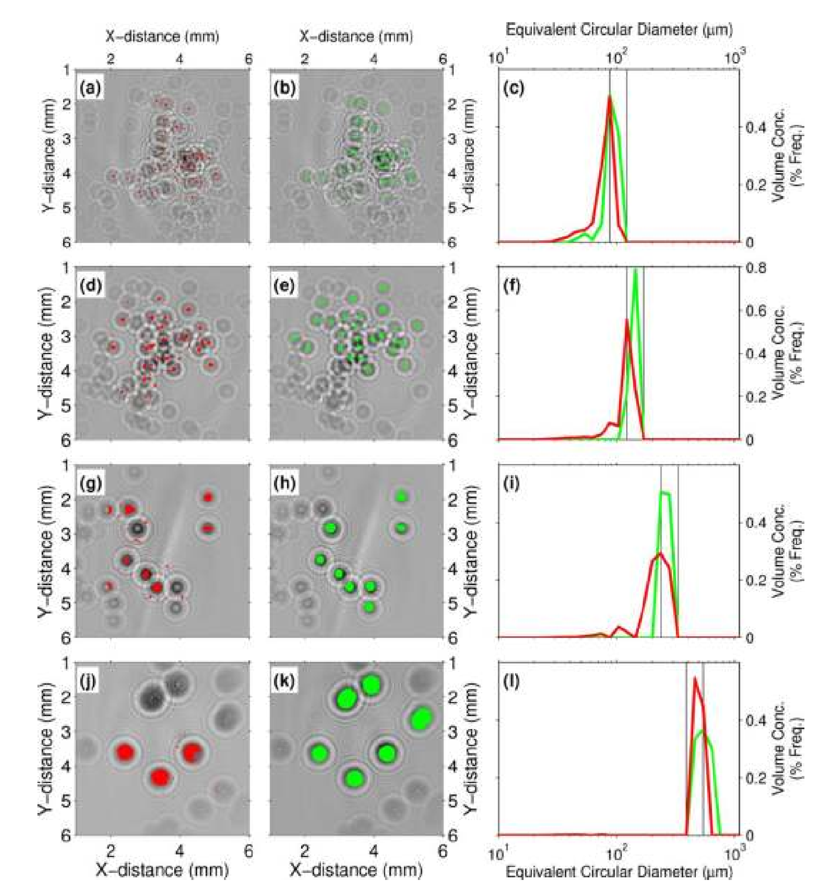


Figure: Example raw hologram containing particles (a), background image (b), and corrected image following background removal (c). In addition to standard background correction, new noise removal steps have been introduced since Graham & Nimmo Smith (2010).

Particles are automatically segmented & sized from slices through volume



- Examples of volume distributions for sieved Basalt spheres which were analysed both automatically (red) and manually (green).
- Vertical black lines indicate the limits of the sieved ranges of each sample for the following sizes: 90μm-106μm (a-c); 125μm-150μm (d-f); 180μm-212μm (g-i); 250μm-300μm (j-l).
- Automatic sizing is in good agreement with the manual and sieved equivalents, but some particles with poor illumination or weak scattering are occasionally over segmented.

Particles can be automatically classified by type based on shape/texture

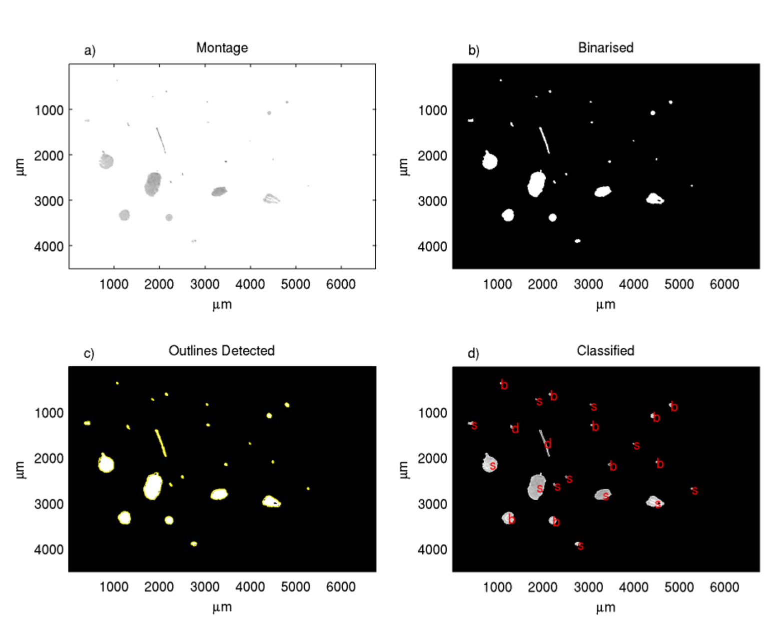


Figure: a) Particles from a single hologram; b) binarised image; c) Binarised image with detected outlines; d) Particles classified ('s' is sand; 'b' is bubble; 'd' is diatom).

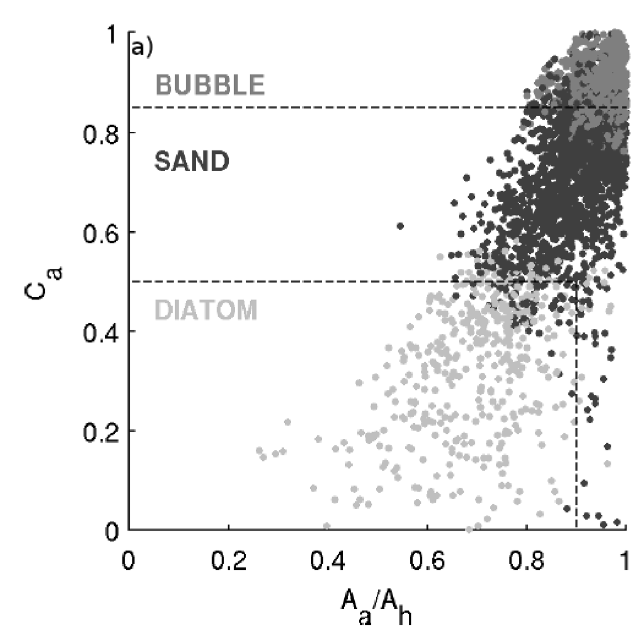


Figure: Shape parameters used for automated classification with data-points shaded according to manual classifications.

Reliable differentiation between sand, bubbles & diatoms in the surf zone

Manual vs. Automated: Diameter

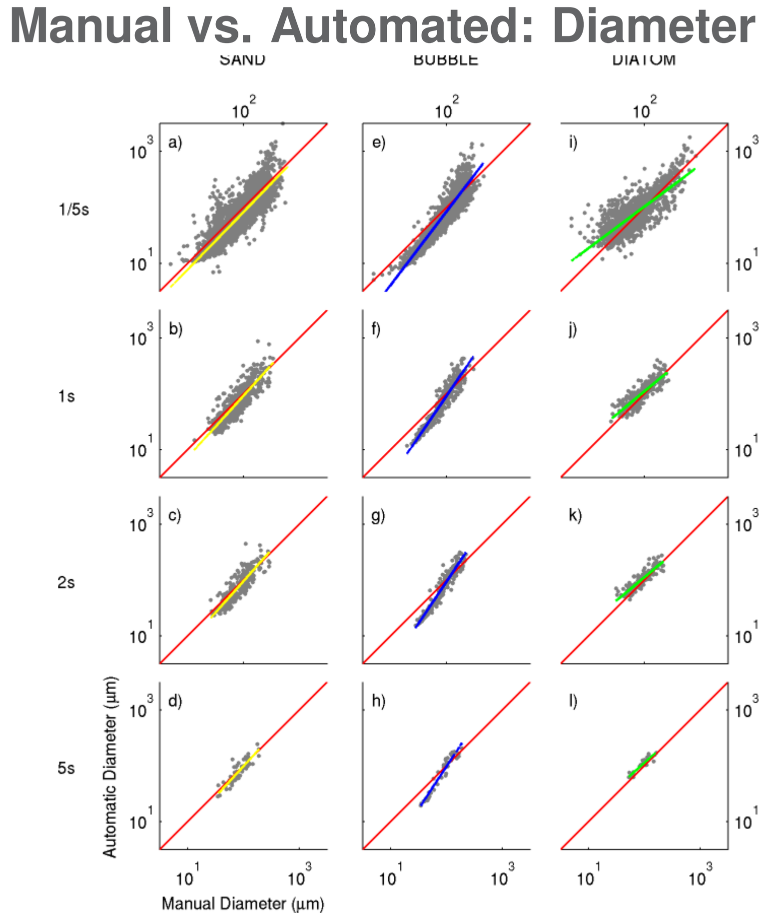


Figure: Sand (a-d), bubbles (e-h) and diatoms (i-l), using 1/5, 1, 2 and 5 second averages.

Manual vs. Automated: Area

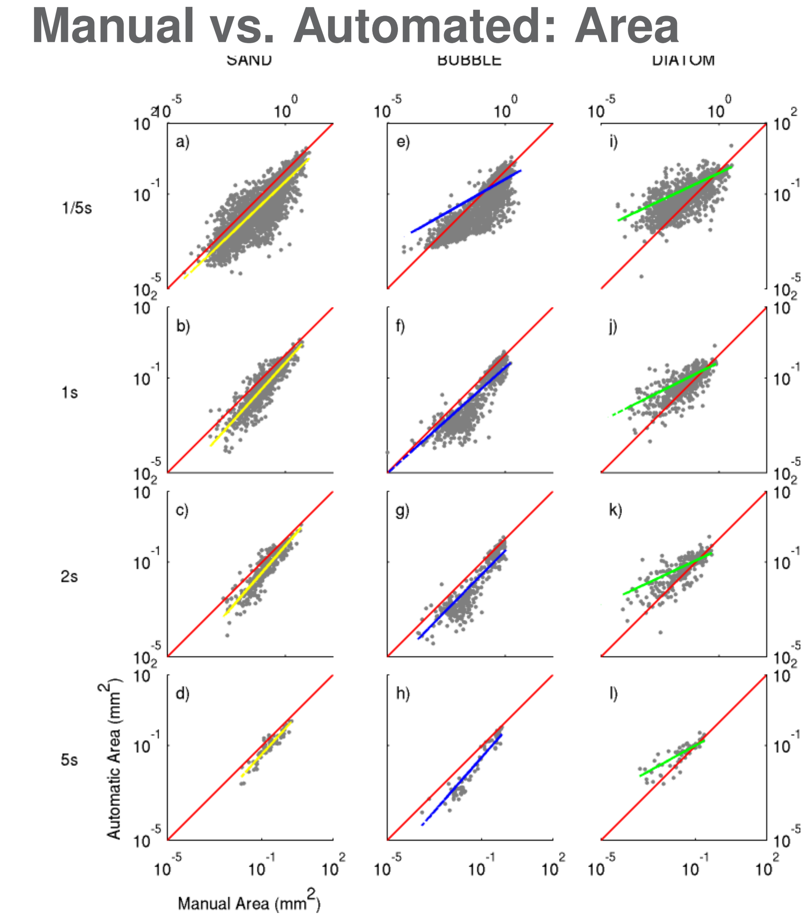


Figure: Sand (a-d), bubbles (e-h) and diatoms (i-l), using 1/5, 1, 2 and 5 second averages.

Cumulative Distribution of RMS Errors Greatly Reduce with Averaging

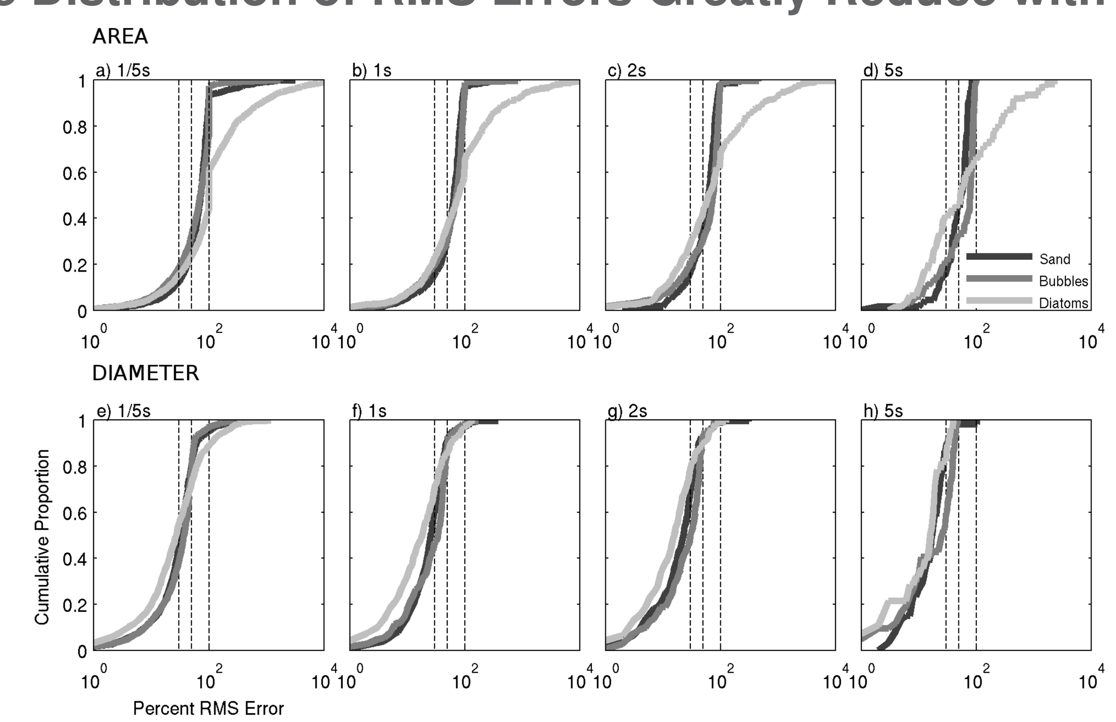


Figure: Proportion of observations which fall within a given % error for sand, bubbles and diatoms, calculated over periods (1/5 to 5 seconds). The dashed lines in each correspond to 30%, 50% and 100% RMS error.

These computational advances make holography a viable alternative to optic/acoustic backscatter technology

- It is possible to reconstruct, segment, size and classify particles imaged by submersible holography, reliably and completely unsupervised.
- Automated classification was capable of successfully differentiating sand grains, bubbles and diatoms, based on particle shape alone.
- Being able to distinguish between sand and other objects improved sand volume-concentration estimates by an average of 46%.
- The method could also be applied to distinguishing oil droplets from plankton and sediments.
- Holography is unique in being able to provide size, shape, concentration and type of particle.

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