Learning Ultra-high-throughput Microscopic Imaging-in-flow for Marine Phytoplankton Monitoring

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The development of automated in-situ analytical instruments of photosynthetically active phytoplankton cells and colonies in natural seawater is of great significance for biological oceanography and HAB monitoring. However, the composition of natural seawater is highly complex. The size range of phytoplankton spans at least 3 orders of magnitude, from single cells <1μm to large diatoms or colonies >500μm. In addition, seawater also contains countless non-phytoplankton particles. These facts present enormous challenges in terms of specificity, sensitivity, and spatial resolution for the field imaging flow cytometers (IFC).

Obviously, HAB observation prefers high-throughput methods in analyzing more seawater within less time to extract realistic phytoplankton information. Since most phytoplankton are tiny, IFCs usually adopt slow flow with high-magnification to obtain sufficient resolution for imaging phytoplankton. However, to enhance imaging throughput, IFCs should use higher flow rates with lower magnifications, though may be very likely at the cost of imaging resolution and quality sacrifice, to gain increased seawater sampling capability. The compromise between imaging resolution and observation accuracy of current IFCs essentially limits their net throughput.

We are trying to combine "low-magnification imaging plus computational super-resolution" in a light-sheet microscopy-in-flow system to balance this trade-off. By building up large-scale phytoplankton image pair datasets, we are training a series of super-resolution deep networks. The preliminary results indicate that the SR models can restore the poorer resolution and quality images acquired by a 5× objective lens into much better images as if were acquired by the IFC system equipped with a 20× lens for downstream task such as recognition or measurement, theoretically achieving a ~40-fold imaging throughput. In this talk, I will report the progress of this research.