Underwater Laguerre Gaussian mode recovery using convolutional neural networks

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Abstract

A typical choice for underwater data collection is to deploy underwater sensors that record data during the monitoring mission, and subsequently recover the information from the sensor's storage unit. However, such an off-line approach cannot deliver real-time information which can be particularly critical in marine life surveillance and natural disaster prevention. Traditionally, acoustic communication has been used for underwater applications, as it can cover long distances, up to several kilometers. However, it is well known that this technology suffers from a very small bandwidth availability, very low celerity, lack of stealth, and large latencies due to the low propagation speed [1]. Recently, high-bit-rate underwater wireless optical communication (UWOC) has lately received a considerable attention since it offers low latency and high bandwidth, which can complement acoustic wave communication [2,3]. One way to increase the bandwidth of this technology is to use the orbital angular momentum (OAM) of light as an additional degree of freedom [4,5]. To further scale the transmission capacity of underwater links, a more optimal choice would be the use of the full Laguerre Gaussian mode basis [6]. In this context, we use LG modes as a communication alphabet to encode information underwater. We rely on convolutional neural networks (CNNs) to recover the initially transmitted modes to avoid the use of projection methods and bulky mode sorters, which can be unpractical for out of laboratory underwater experiments. Different encoding schemes are proposed to transmit a high amount of information over an underwater communication link established using a spatial light modulator and a CMOS camera. A 100 % recovery accuracy is obtained at clear water and a high recovery fidelity over a wide range of underwater turbulence regimes induced by turbidity, bubbles, temperature in-homogeneity, and salinity. The simultaneous identification of multiple co-propagating spatially-separated LG modes is further demonstrated.

References

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