Advancing Acoustic Fish Tracking with Deep Learning

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INSIDE OUT

Tracking the movements of marine animals in space and time plays an increasingly important role in the sustainable management of ocean resources. In the context of fishery operations research, there is a desire to utilize fish tracking technology to gain a better understanding of fish movement, allowing fisheries to optimize both operations and sustainability by improving the targeting of desired fish stocks while reducing bycatch.

However, existing fish tracking solutions do not work well at the spatial scales of interest to the fisheries (~ 100 km^2). Innovasea, a leading ocean tech company headquartered in Halifax, N.S., is seeking to solve this problem through the OceanAware project supported by Canada's Ocean Supercluster. Innovasea has invented an improved fish tracking solution that employs high-frequency signals and a novel encoding scheme. The new solution has proven highly resilient to noise and hence enabled the detection of tagged fish at farther ranges and/or in noisier acoustic environments than previously possible. Therefore, it has the potential to enable the tracking of fish at the spatial scales of open ocean fisheries. However, the new solution has proven difficult to scale because the novel coding scheme requires manual analysis to reconstruct accurate trajectories.

In this article, we discuss how deep learning techniques can help automate identification of acoustic signals transmitted with this novel encoding scheme. We adapt a neural network architecture known as UNet, originally developed for solving image segmentation tasks, to analyze acoustic tag data achieving near-human accuracy. This allows us to solve the scalability problem, paving the way for applications to fishery operations.

In the encoding scheme of the new tracking solution, the fish tags transmit short-duration acoustic pulses, referred to as "pings," at regular intervals that are detected by dedicated underwater receivers. The tags are then identified from the observed delay between successive pings. In typical applications, the delay is between 1 s and 10 s, where shorter periods yield higher spatial resolution, but also shorten the tag's lifetime due to increased energy consumption. Moreover, the tags can be configured to emit not one, but two, closely spaced pings. Varying the temporal separation of the two pulses gives another way to distinguish between tags.

The strength of the Innovasea encoding scheme lies in its simplicity. Other commonly used encoding schemes employ complex sequences of pulses. Such schemes allow tags to be uniquely identified based on a single transmission but consume more energy and are more susceptible to noise interference. As a direct result, the novel encoding scheme has the potential to provide higher tracking resolution and enhanced range.

While the new Innovasea encoding scheme sounds simple to implement, in practice it can be rather challenging to identify acoustic tags

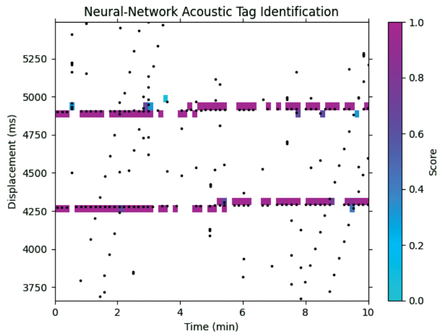

Figure 1: The UNet has correctly identified the pings from an acoustic tag that transmits a double pulse with a repetition period of 9,152 ms and an inter-pulse separation of 628 ms. The colours indicate the certainty of the UNet identification, quantified as a score between 0 and 1.

based on their ping rate, especially if multiple tags are present simultaneously. Moreover, natural environment noise signals and multi-path reflections of pings clutter the picture. To facilitate the identification of tags based on their ping rate, Innovasea has developed a 2D "image" representation in which the received pings are plotted according to their time of arrival (x) and their displacement (y) with respect to a set clock rate. In this representation, pings originating from a (stationary) tag with a ping rate that matches the set clock rate will describe a horizontal track, allowing them to be identified and "marked" by a human analyst through visual inspection. As a tagged fish moves, the track may deviate slightly from horizontal, conveying important information about the fish's motion, but also complicating the marking task. An example of the image representation can be seen in Figure 1.

Thus, the problem of decoding the acoustic data has effectively been transformed to the task of recognizing track-like features in an image – a task that deep neural networks have proven highly successful at solving in recent years. In particular, the UNet architecture has been successfully trained to solve such "segmentation" tasks in a variety of domains including geospatial and medical imagery.

In a collaboration between Innovasea, DeepSense, and the Institute for Big Data Analytics at Dalhousie University, the UNet has now been successfully adapted to yet another domain, acoustic fish tracking. Leveraging a large, manually annotated, acoustic dataset and employing several data augmentation techniques, we have trained a UNet to identify the track-like features produced by fish tags. The dataset derives from a month-long study performed in a shallow river environment, employing several dozen tags and 10 receivers. When the trained UNet was asked to identify tags not seen during the training phase, it was able to do so with an accuracy of over 95%, which is close to the accuracy achieved by human analysts. In Figure 1, the UNet has correctly identified the pings from an acoustic tag that transmits a double pulse with a repetition period of 9,152 ms and an inter-pulse separation of 628 ms. The colours indicate the certainty of the UNet identification, quantified as a score between 0 and 1.

It remains to be established how well the UNet trained on this particular dataset generalizes to entirely new acoustic environments and study settings. However, the results obtained so far are already highly encouraging. Deep learning can, if not entirely eliminate, drastically reduce the need for manual analysis of the data generated by Innovasea's new encoding scheme, thus paving the way for large-scale application to fisheries operation. We are now working on improving and optimizing the UNet model so that it can be integrated into Innovasea's operations.

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