

Supplement S3: Figures and Tables

A deep learning approach to photo-identification demonstrates high performance on two dozen cetacean species.

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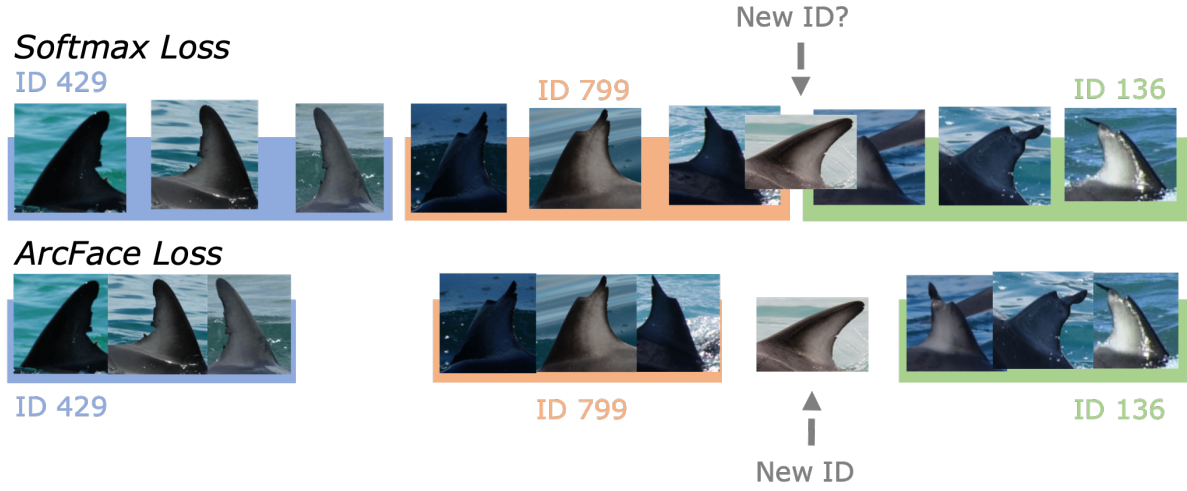


Figure S1: A schematic diagram of the two loss functions, inspired by Figure 3 in Deng *et al.* (2019). Each dorsal fin represents the image’s projection onto an abstract, high-dimensional space (softmax loss) or a hypersphere (ArcFace loss). The three colored boxes contain three images of a known individual dusky dolphin (*Lagenorhynchus obscurus*). Additionally, there is a tenth image of a “new individual,” i.e., one not in the training set. The white space between the boxes represents the decision boundaries. For softmax loss, the decision boundaries are so close that the identity of the new individual is ambiguous. In ArcFace, each sample has been pushed closer to its class center, and away from the other centers, such that we can confidently classify the individual as new.

Table S1: Data augmentations used before training, implemented in the Albumentations library. `translate_percent` dictates the proportion of image that is translated. `scale` dictates the proportion of the image that is cropped, while `ratio` dictates the range of aspect ratio of the origin that is cropped. `blur_limit` dictates the max kernel size for blurring the image. `grid` is the size of the grid for splitting the image.

Albumentations Function	Arguments
Affine	<code>rotate=(-15, 15),</code> <code>translate_percent=(0.0, 0.25)</code>
RandomResizedCrop	<code>image_size[0], image_size[1],</code> <code>scale=(0.9, 1.0), ratio=(0.75, 1.33)</code>
ToGray	<code>p=0.1</code>
GaussianBlur	<code>blur_limit=(3, 7), p=0.05</code>
GaussNoise	<code>p=0.05</code>
RandomGridShuffle	<code>grid=(2, 2), p=0.3</code>
Posterize	<code>p=0.2</code>
RandomBrightnessContrast	<code>p=0.5</code>
Cutout	<code>p=0.05</code>
RandomSnow	<code>p=0.1</code>
RandomRain	<code>p=0.05</code>
HorizontalFlip	<code>p=0.5</code>

Table S2: Predictive performance by catalog, including the mean average precision (MAP), Top1 Accuracy, and number of images precision score.

Species	Location	MAP	Top1	Precision score					
				0	1/5	1/4	1/3	1/2	1
Beluga	Alaska	0.75	0.70	156	12	20	30	41	612
	Quebec	0.84	0.79	232	26	38	63	136	1900
Blue whale	Chile	0.74	0.65	67	6	4	22	62	297
	US West Coast	0.77	0.72	76	7	8	17	27	353
Bryde’s whale	São Paulo	0.88	0.85	3	0	1	1	2	40
Commerson’s dolphin	Falkland Islands	0.87	0.79	3	0	1	0	8	46
Common bottlenose dolphin	Scotland	0.94	0.93	67	7	22	15	56	2108
	Adriatic Sea	0.93	0.88	1	0	2	3	5	83
	Florida	0.98	0.98	2	3	2	2	2	517
	Hawai’i	0.96	0.94	6	0	1	6	8	350
Common dolphin	Aegean Sea	0.84	0.79	10	0	0	4	6	75
Common minke whale	Iceland	0.64	0.54	20	0	6	7	11	51
	British Columbia	0.77	0.66	9	11	22	28	37	206
Cuvier’s beaked whale	California	0.71	0.56	20	2	15	34	59	164
Dusky dolphin	New Zealand	0.88	0.83	99	5	8	26	174	1480
False killer whale	Guadeloupe	0.87	0.85	1	0	0	1	0	11
	New Zealand	0.99	0.98	10	1	1	1	9	1132
	Hawai’i	0.98	0.97	2	0	1	0	0	109
Fin whale	US West Coast	0.85	0.79	29	3	12	28	55	469
Gray whale	Oregon	0.86	0.84	40	6	5	9	15	384
Humpback whale	Queensland	0.83	0.74	8	3	2	5	23	116
	Global	0.82	0.77	356	28	45	90	245	2521
Killer whale	McMurdo Sound	0.86	0.82	67	2	5	16	37	591
	Western Australia	0.98	0.97	6	0	2	0	6	426
Long-finned pilot whale	New Zealand	0.95	0.90	1	0	1	1	10	123
Melon-headed whale	Hawai’i	0.94	0.89	9	1	1	7	83	840
Pacific white-sided dolphin	British Columbia	0.88	0.79	1	1	0	6	15	89
Pantropical spotted dolphin	Guadeloupe	0.91	0.88	3	0	0	1	5	63
	Hawai’i	0.90	0.81	0	0	3	9	36	206
Pygmy killer whale	Guadeloupe	0.97	0.95	0	0	0	1	1	35
Rough-toothed dolphin	Guadeloupe	0.76	0.72	7	1	0	3	1	31
Sei whale	Falkland Islands	0.93	0.91	5	1	0	6	7	184
Short-finned pilot whale	Guadeloupe	0.73	0.65	9	1	1	4	7	41
	Mariana Islands	0.97	0.95	3	2	1	9	7	418
	Hawai’i	0.94	0.89	1	0	0	3	14	146
Southern right whale	New Zealand	0.63	0.53	122	12	15	30	65	277
Spinner dolphin	Red Sea	0.97	0.95	1	0	0	2	1	77
	Mariana Islands	0.95	0.94	10	1	1	2	8	351
	Hawai’i	0.94	0.90	5	2	2	8	46	550

References

Deng, J., Guo, J., Xue, N. & Zafeiriou, S. (2019) Arcface: Additive angular margin loss for deep face recognition. *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*, pp. 4690–4699.