Open-source deep learning models for acoustic detection and classification of orcas

> Oliver S. Kirsebom MERIDIAN, Dalhousie University (On behalf of the HALLO team)

2021.12.02, Seattle, WA 181st Meeting Acoustical Society of America Special Session: Applications of Bioacoustics in Killer Whale Conservation (4pAB10)

The HALLO Project

- HALLO = Humans and ALgorithms Listening for Orcas
- Inter-institutional & multi-disciplinary
- \$550k in support from Fisheries and Oceans Canada (DFO)
- Two-year project (ending March 31st, 2022)
- **Goal:** Develop deep learning models for detecting and classifying the vocalizations of killer whales in the coastal waters of BC and WA, esp. Southern Residents
- Key component of real-time movement forecasting system based on PAM and visual sightings



Contributions

• Trained detectors and classifiers

- Deep learning KW detector (this talk)
- Southern Resident call-type classifier (next talk)

• Annotated datasets

- Compiling existing annotated datasets
- Producing new ones

• Software tools

- Web annotation app¹
- PAMGuard compatibility

• Training

• Tutorial at DCLDE 2022 (proposal submitted)

¹Poster by F. Frazao: "Novel software for deep-learning based acoustic data analysis" (3aAB7)

Open science

- Web portal for sharing ¹
 - \circ trained models
 - \circ annotated datasets
- Software development best practices ²
 - Well-documented code
 - Version control
 - Open source, etc.

¹ Poster by F. Frazao: "Novel software for deep-learning based acoustic data analysis" (3aAB7)

² Tutorial Lecture: Software Best Practices
Wu-Jung Lee, Fabio Frazao, Valentina Staneva
(Monday 7-9 PM)

Coming soon ...

HALLO Datasets





Methodology



Deep learning model





Magnitude Spectrogram (dB)

- Window: 0.051 s
- Step: 0.01955 s
- Hamming window function
- Tonal noise reduction (row-wise median subtraction)
- Normalize to $\mu = 0$ and $\sigma = 1$

Implemented with Ketos:

https://docs.meridian.cs.dal.ca/ketos/



KW

Detector

Poster 3aAB8: "Ketos - A deep learning package for creating acoustic detectors and classifiers"

Sources of acoustic data



Additional data sources:

- ONC, esp. Barkley Canyon¹
- DFO (James Pilkington)

¹ J. Kanes: "Marine mammal phonations of Barkley Canyon: a publicly available annotated data set" (1pABb3)

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Sources of acoustic data



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Sources of acoustic data



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Location	Depth (m)	Duration	Temporal extent	Ecotypes	Pods	KW calls	Other species	Other noise
Boundary Pass	193	2h:30m	30-min files; 5 days; fall, spring	SR	J, L, K?	1,070	none heard	vessel
Robert's Bank	168	3h:30m	5-min files; >30 days; all year	SR, T	J, L, K?	1,868	HB (51), PWSD (23)	vessel, sonar
Lime Kiln	7	2h:13m	1-min files; continuous; summer	SR, T	J, L, K	1,483	fish (23)	vessel
Orcasound Lab	5-20	0h:51m	1-min files; 2 days; summer, fall	SR	J, L	532	none heard	vessel
Barkley Canyon	392	6h:05m	5-min files; 5 days; spring, summer	T, (SR?)	-	401	PWSD (450), HB (5)	vessel, electronic

We are working on creating more test sets ...

The more variety, the better!

KW detector - first results



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Future directions

Short term: (before March 31st, 2022)

- Expand training set:
 - hard negatives (e.g. humpback, PWSD)
 - more hydrophones (e.g. Haro Strait nodes)
 - synthetically augmented samples (e.g. mixup)
- Create more test sets
- Explore efficacy of transfer learning for adapting to unseen acoustic environments

Longer term:

- Develop more sophisticated deep learning models that,
 - consider more temporal context (e.g. Sequence models)
 - utilise time-domain aural features
- Find ways to leverage weakly labeled data

PAMGuard deep learning module

- New module in PAMGuard
- Run pre-trained models
 - AnimalSpot
 - Ketos
 - Generic model





(Jamie MacAulay)

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https://docs.meridian.cs.dal.ca/ketos/

We are not alone!

SCIENTIFIC REPORTS natureresearch

ORCA-SPOT: An Automatic Killer Whale Sound Detection Toolkit Using Deep Learning

Christian Bergler¹, Hendrik Schröter¹, Rachael Xi Cheng², Volker Barth³, Michael Weber³, Elmar Nöth¹, Heribert Hofer ^{2,4,5} & Andreas Maier ¹

Applied Acoustics 150 (2019) 169-178



Contents lists available at ScienceDirect

Applied Acoustics

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and Whales

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alous for The Wall Street Journal

CROLL

isten to the full podcast here Michael Bucher and Janet Rabin | Photographs by Kam

Coexist

journal homepage: www.elsevier.com/locate/apacoust

Whistle detection and classification for whales based on convolutional neural networks



Jia-jia Jiang^{a,*,1}, Ling-ran Bu^{a,1}, Fa-jie Duan^a, Xian-quan Wang^a, Wei Liu^b, Zhong-bo Sun^a, Chun-yue Li^a

^a The State Key Lab of Precision Measuring Technology and Instruments, Tianjin University, 92 Weijin Road, Nankai District, Tianjin, China ^b The Department of Electronic and Electrical Engineering, University of Sheffield, United Kingdom

Google Builds AI to Help Ships ificial intelligence trained to detect orca ounds in noisy waters is helping protect

Google



Canada





Deep Learning and Domain Transfer for Orca Vocalization Detection

Paul Best*, Maxence Ferrari*[†], Marion Poupard*[‡], Sébastien Paris*, Ricard Marxer*, Helena Symonds § and Paul Spong §, Hervé Glotin

> *Univ. Toulon, Aix Marseille Univ. CNRS. LIS. DYNI Marseille, France [†]LAMFA. CNRS Amiens France [‡]BIOSONG SARL France [§]OrcaLab Alert Bay Email: paul.best@univ-tln.fr

Summary

- HALLO = Humans and ALgorithms Listening for Orcas
- Deep learning models for detecting and classifying killer whale vocalisations, with focus on Southern Residents
- Key component in real-time movement forecasting system
- Open-science approach:
 - Models and annotated datasets will be freely available
 - Web portal under construction ...
- Software tools:
 - Web annotation app
 - PAMGuard deep learning module

Stay tuned!

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The HALLO team

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Thank you!

More HALLO talks:

Ruth Joy & Marine Randon (4pAB3) Paul Nguyen Hong Duc (4pAB11) Fabio Frazao (3aAB7)