Quick guide to UAS-based photogrammetry of whales

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Photogrammetry Overview

Be sure to obtain all necessary permits before conducting field work, i.e., pilot license (FAA Part 107), marine mammal research (NMFS). To obtain measurements from an aerial image, measurements made in pixels are multiplied by the ground sampling distance (GSD) to convert to standard units (e.g., meters) (Fig. 1A). GSD represents the distance on the ground that the length of each pixel represents (i.e., the linear size of the pixel) and thus sets the scale of the image (m/px or cm/px). Figure 1A describes how GSD is dependent on the camera sensor, focal length lens, and altitude. Thus, Unoccupied Aircraft Systems (UAS) equipped with different cameras and focal length lenses will have inherent differences in GSD as altitude increases (Fig. 1B). A larger GSD increases the length each pixel represents in a photo, potentially obscuring important features in the photo and introducing measurement error.

Add a laser altimeter (LIDAR) to UAS

All UAS come with an onboard barometer for recording altitude, but adding a laser altimeter will dramatically improve accuracy (see Bierlich et al., 2021a)

- Manuscript: https://www.int-res.com/abstracts/meps/v673/p193-210/
- Most studies have used a LightWare SF11/C LIDAR
    - https://www.mouser.com/datasheet/2/321/28054-SF11-Laser-Altimeter-Manual-Rev8-1371857.pdf
- See Dawson et al., 2017 for description of installation and setup of laser altimeter.
    - Manuscript: https://www.frontiersin.org/articles/10.3389/fmars.2017.00366/full
- Note, we also developed a lidar housing that can be easily installed and swapped between DJI Phantoms and Inspires. Contact kevin.bierlich@oregonstate.edu for more details.

Field protocol

Before Take-off

- Record the launch height of the UAS, measured from the camera lens to the waterline. So, if performing hand launch and recovery from a boat, record the launch height of the person holding the drone (can be done one time for each person-boat and applied to all flights).
- ***Important*** Before take-off, record video of the GPS time (to the second) to sync UAS video and laser altimeter.
    - I recommend using a BadElf GPS unit (https://bad-elf.com/), which can be paired to an iPhone or iPad to display the GPS time

Collect Training data

- Bierlich et al. (2021a, b) developed a Bayesian statistical model to incorporate uncertainty associated with UAS-based measurements by using measurements of known-sized objects at various altitudes as training data to predict the length measurements of unknown sized whales.
    - Bierlich et al. (2021a): https://www.int-res.com/abstracts/meps/v673/p193-210/
    - Bierlich et al. (2021b): https://www.frontiersin.org/articles/10.3389/fmars.2021.749943/abstract
- Collect training data by flying over a known-sized object (e.g., a board) floating at the surface at altitudes that encompass the range used to collect imagery of whales (e.g., within 10-120 m).

- Training data is preferably collected during the flight over whales (e.g., at the start of each flight), but can also be collected before or after the field season.
- Bierlich et al., 2020 also has freely available training data for some UAS aircraft
    - https://research.repository.duke.edu/concern/datasets/fq977v51n?locale=en

Flying over whales

- Collect video of whales when they are flat and straight at the surface with minimal wake or refraction. Ensure camera is nadir (90˚, straight down) to obtain an accurate altitude reading. Typical flight altitude over gray whales are ~25 – 30 m using a Phantom 4 Pro and ~30 – 40 m using an Inspire 2.

Data processing

- Import videos into VLC Media Player (https://www.videolan.org)
- Add subtitles to the video to obtain barometer altitude
- Collect still frames of the whale in the video using the Snapshot function
    - Whale should be straight with minimal curvature, flat at the surface, and with minimal wake and refraction around the edges of the body
- Record the time in the video of each snapshot (i.e., 1 min 21 s). Then add this snapshot time to the GPS time obtained from filming the digital clock. Align this summed time with the matching time from the laser altimeter to obtain the altitude the snapshot was captured at.
- Rank each photo for quality in measurability following Christiansen et al., 2018
    - Manuscript: https://www.int-res.com/abstracts/meps/v592/p267-281
    - See supplementary material for guide on seven attributes for measurability quality http://www.int-res.com/articles/suppl/m592p267_supp/

Photogrammetry

- Import each snapshot into MorphoMetriX open-source photogrammetry software to make measurements of the whale (Torres and Bierlich, 2020)
    - Manuscript: https://joss.theoj.org/papers/10.21105/joss.01825
    - Repository: https://github.com/wingtorres/morphometrix
- Collate MorphoMetriX outputs into a single datasheet using CollatriX (Bird and Bierlich, 2020)
    - Manuscript: https://joss.theoj.org/papers/10.21105/joss.02328
    - Repository: https://github.com/cbirdferrer/collatrix#installation

  CollatriX can calculate many whale body condition metrics, including the Body Area Index (BAI; Burnett et al 2018), which is a scale-invariant value effective for comparison across individuals and groups of animals. Relative to other tested body condition indices, BAI has the lowest uncertainty (Bierlich et al. 2021b).

Incorporate Measurement Uncertainty

- Set up Bayesian statistical model to incorporate measurement uncertainty associated with:
    - Total body length and morphometric relationships (e.g., rostrum to blowhole and total body length) following Bierlich et al., 2021a
        - Manuscript: https://www.int-res.com/abstracts/meps/v673/p193-210/
        - Repository: https://research.repository.duke.edu/concern/datasets/fq977v51n?locale=en
    - Total body length and body condition, e.g., body area index (BAI), following Bierlich et al., 2021b
        - Manuscript: https://www.frontiersin.org/articles/10.3389/fmars.2021.749943/abstract
        - Repository: https://github.com/KCBierlich/Body_Condition_Analysis

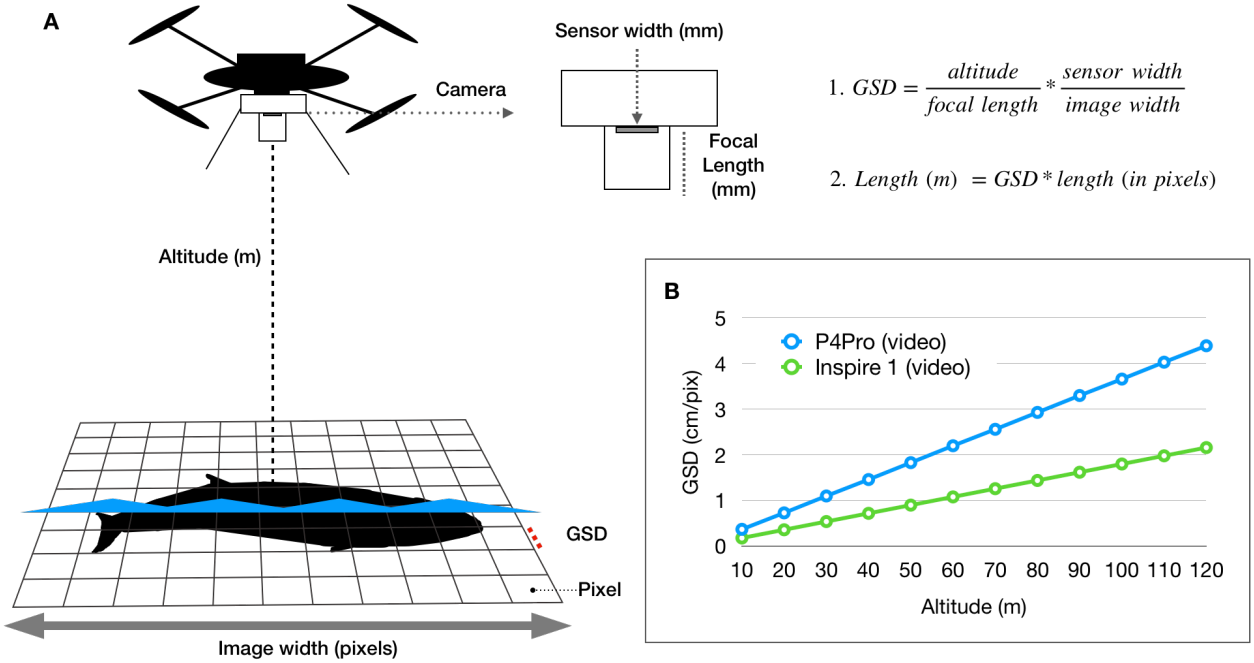

Figure 1: Overview of photogrammetry methods and calculating ground sampling distance (GSD). A) Photogrammetry methods for how each image is scaled to convert measurements in pixels to standard units (e.g., meters). Altitude is the distance between the camera lens and whale (usually at the surface of the water). Figure from Torres and Bierlich (2020). B) The exact (not accounting for distortion or altitude error) ground sampling distance (GSD) for two UAS platforms commonly used to obtain morphological measurements of cetaceans. The difference in GSD between the P4Pro and Inspire 1 is due to the difference in sensor width and focal lengths of the cameras used. Figure from Bierlich et al. (2021a).

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