HOTSPOTTER: LESS MANIPULATING, MORE LEARNING, AND BETTER VISION FOR TURTLE PHOTO-IDENTIFICATION

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INTRODUCTION

- Ability to distinguish individual animals in a population is key to conducting long-term population studies.
- Common way to identify individuals in turtle studies has been through flipper tagging. Method has some drawbacks – tags corroded, shed, lost (Balazs, 1982), or removed (Dunbar et al., 2014).
- When flipper tags are lost, ability to gather important data on animal over time (growth rates, home range, migration, age-at-maturity) is also lost.
- Animal photography is improving with ease of digital photo capture. Can be used by experts and citizen scientists.
- Photo ID (PID) has been used successfully in many studies of various animal taxa, but is relatively new to sea turtle studies (Schofield et al., 2004; Jean et al., 2010; Dunbar et al., 2014).
- Common challenges are: 1) need to acquire high-quality images from same angle, 2) time-consuming pre-processing before submitting to database, 3) potential for high numbers of false positive matches, and 4) requirement for manual verification of many potential outputs.
- We report on HotSpotter (Crall et al., 2013) that provides better methods for sea turtle PID than previously used methods.
- HotSpotter uses scale invariant feature transform (SIFT) (Lowe, 2004). Keypoint locations are compared and scores combined to rank animals in a database for potential matches.

METHODS

- We collected photographs of turtles in and out of water (n = 251 in 2014 and 2015; n = 1,157 in 2016) in the Sandy Bay West End Marine Reserve (SBWEMR) **(Fig. 1)**.

Fig. 1. Study site of Sandy Bay West End Marine Reserve, Roatán, Honduras.

- Photos from 2014 and 2015 uploaded into HotSpotter and "chip" (Area of Interest) added to each photo **(Fig. 2A)**.
- HotSpotter assigns key feature points (small dots) **(Fig. 2B)**.
- Ran query of each photo and named photos of same turtle with same naming label. Affine keypoints shown by ellipsies **(Fig. 2C and D)**.
- Uploaded new photos from 2016 and queried each new photo.
- Analyzed accuracy of first and second choice matches.

METHODS cont.

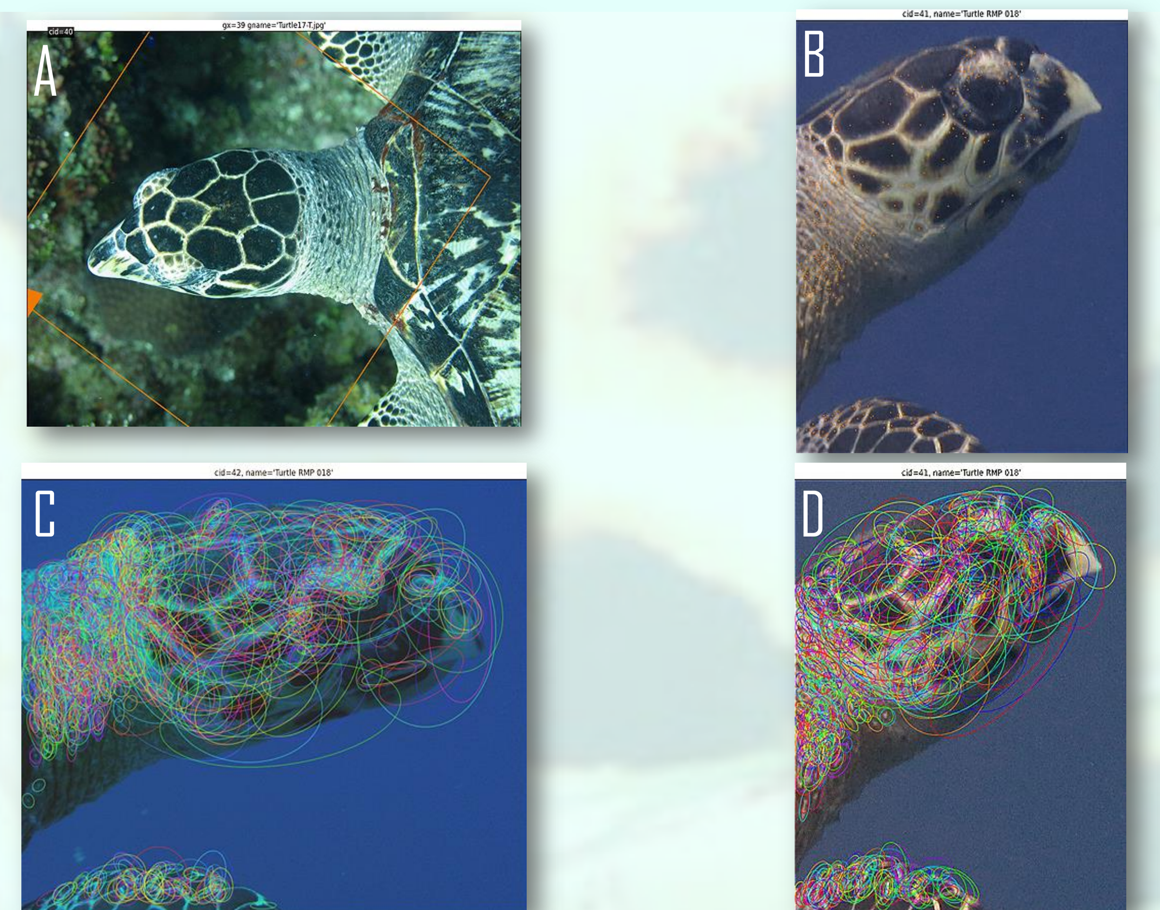
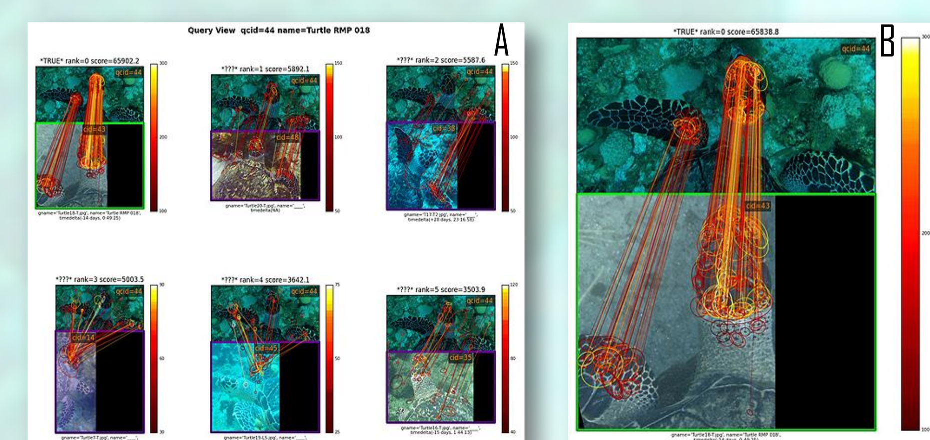


Fig. 2. Steps in the HotSpotter analysis. (A) User-defined "chip"; (B) HotSpotter-selected key features; (C and D) affine (elliptical) keypoints used to compare features between photos for matching.

RESULTS

Fig. 3. Feature matching. (A) each query feature matches 1- 10 features in the database photo, forming a potential match pair of photos. (B) lines represent a corresponding feature colored by its match score.



We found strong feature matching scores for 1st and 2nd match choices (Fig. 3, Table 1). We excluded false positive matches for new turtles ("FP(New)") recognizing the program is unable to return a "no match" result. When first and second match choices are combined, accuracy was >81% (Fig. 4).

	Mean score ± 1SD (n) [range] for 1st Choice	Mean Score ± 1SD (n) [range] for 2nd Choice	Total n in Both Choices
True Matches	8,373 ± 10,058 (58) [347.8 – 65,898.9]	4,419 ± 3,249 (43) [458.8 – 12,332.7]	61
False Positives	1,043 ± 5712 (17) [354.1 - 2,233.5]	895 ± 589 (32) [0 – 2,359.4]	14
False Positives (New)*	1,480 ± 773 (36) [417.3 – 3,871.6]	1,068 ± 388 (36) [315.1 – 2,039.8]	36
Total Tests	(111)	(111)	(111)

Table 1. Number of true matches, false positives, and false positive (new). * = removed from analysis because program cannot return a "no match" for new turtles.

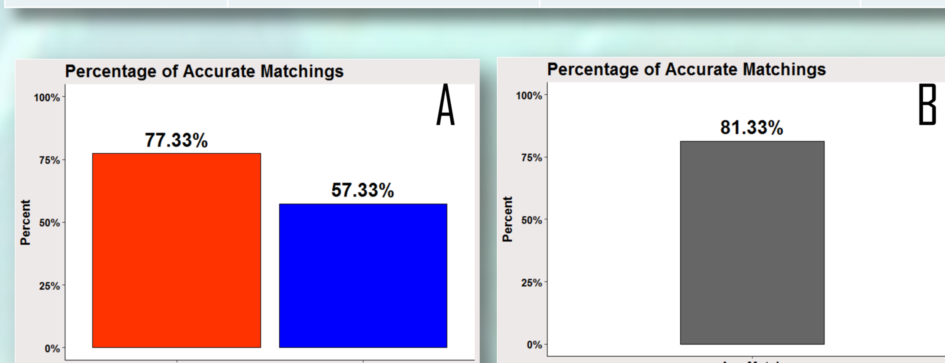


Fig. 4. Accuracy analyses. (A) Accuracy of 1st and 2nd choice matches. (B) Combined 1st and 2nd choice accuracy at finding true matches.

DISCUSSION

- Scores for correct matches were significantly higher (ANOVA) than for false positive matches (FP), and for FP(New) matches.
- Geometric mean scores for FP and FP(New) < 4,000. Scores > 4,000 resulted in accurate matches.
- We found HotSpotter able to address most of the common challenges to other computer PID systems for sea turtles.
- HotSpotter uses photos of different qualities and from different angles for computer training. For HotSpotter, this is an advantage rather than disadvantage (as in some other PID systems).
- Pre-processing time is limited to assigning a "chip" (two points on the photo) and placing photos in similar orientations.
- Program only returns the six most likely matches and filters out all unlikely matches based on ranked scoring. Need for manual verification is limited, rather than reviewing dozens of potential matches.
- HotSpotter can be integrated into the Internet of Turtles and can facilitate mobile applications for data and photo gathering, such as TURT and RASTR (Baumbach and Dunbar, 2017).

ACKNOWLEDGMENTS

We thank the Roatan Dive Center for their partnership with ProTECTOR Inc. And Ted Anger of ScubaTed for collecting and recording photographs of turtles, Jimmy Miller, and Lidia Salinas for logistical support, and Lidia Salinas for securing all Honduras research permits. We are grateful to Susanna Ferriera Catrileo (ICF Tegucigalpa), and Cindy Flores (ICF Roatán) for the ICF permit, and Eloisa Espinosa and Ing. Blass Cabrera for the DIGEPESCA/SAG permit. Dennys Estevez (RCG-LLU) assisted with data analyses. Tanya Berger-Wolf, Chuck Stewart, Jason Holmberg, and Jon Crall were supported by NSF Awards 1453555 and 1550880, and through gifts from WildMe. This research was also funded by ProTECTOR Inc., and the Department of Earth and Biological Sciences (LLU).

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