

Towards Automated Monitoring of Animal Movement Using Camera Networks and Deep Learning

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Arizona Game and Fish Department

Mission: To conserve, enhance, and restore Arizona's diverse wildlife resources and habitats through aggressive protection and management programs, and to provide wildlife resources and safe watercraft and off-highway vehicle recreation for the enjoyment, appreciation, and use by present and future generations

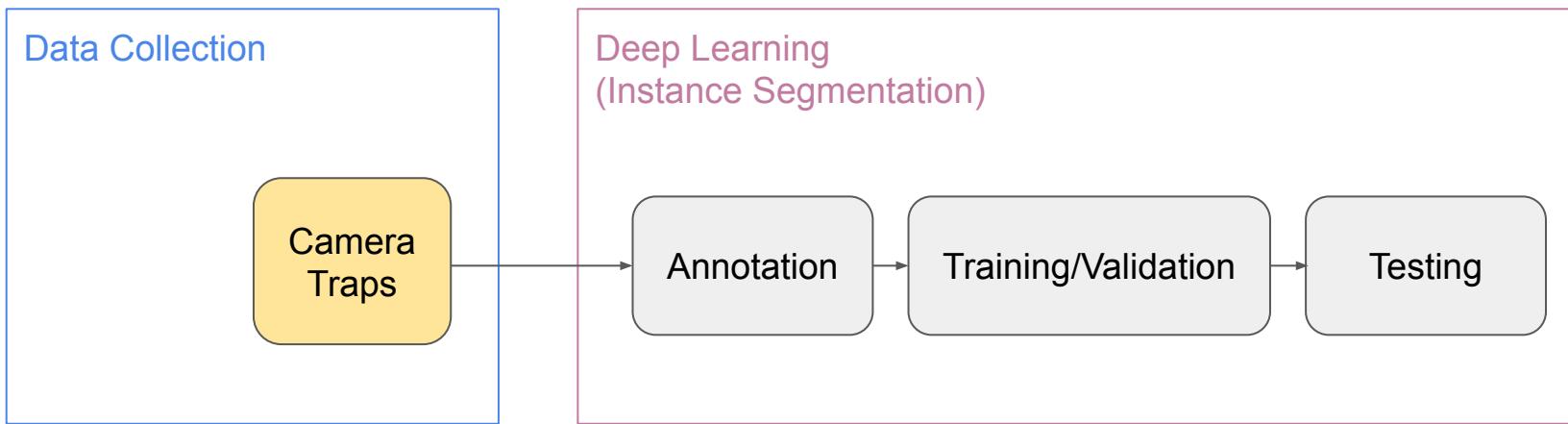


Contracts Branch

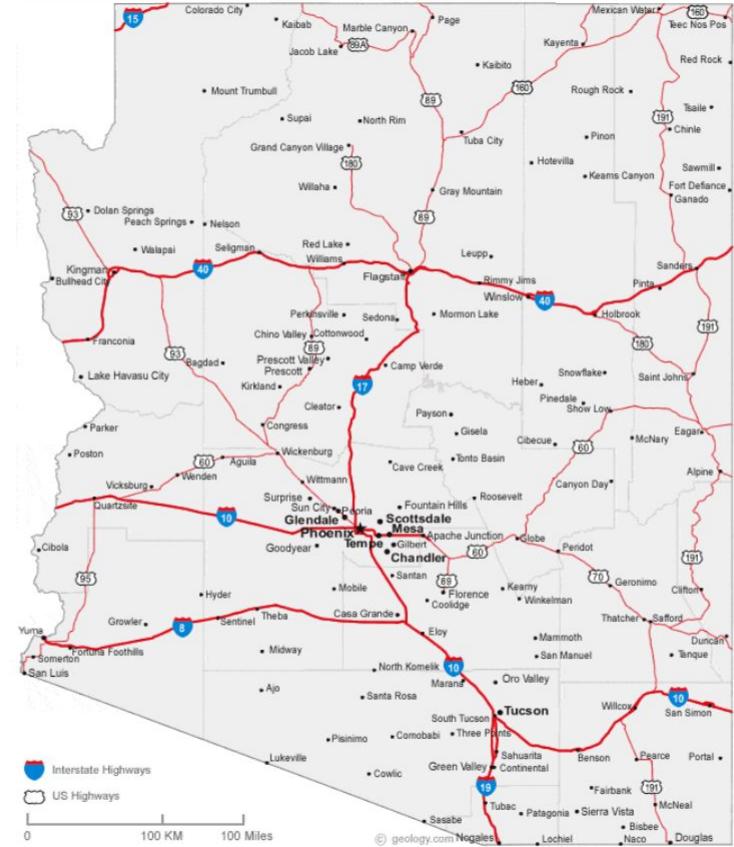
To monitor wildlife interactions with highways in order to make the most effective management decisions

Our Goals

- Make data analysis more efficient
- Minimize observer-specific bias
- Compare accuracy/precision of classification to human observers



Arizona Highways



Wildlife-Vehicle Collisions

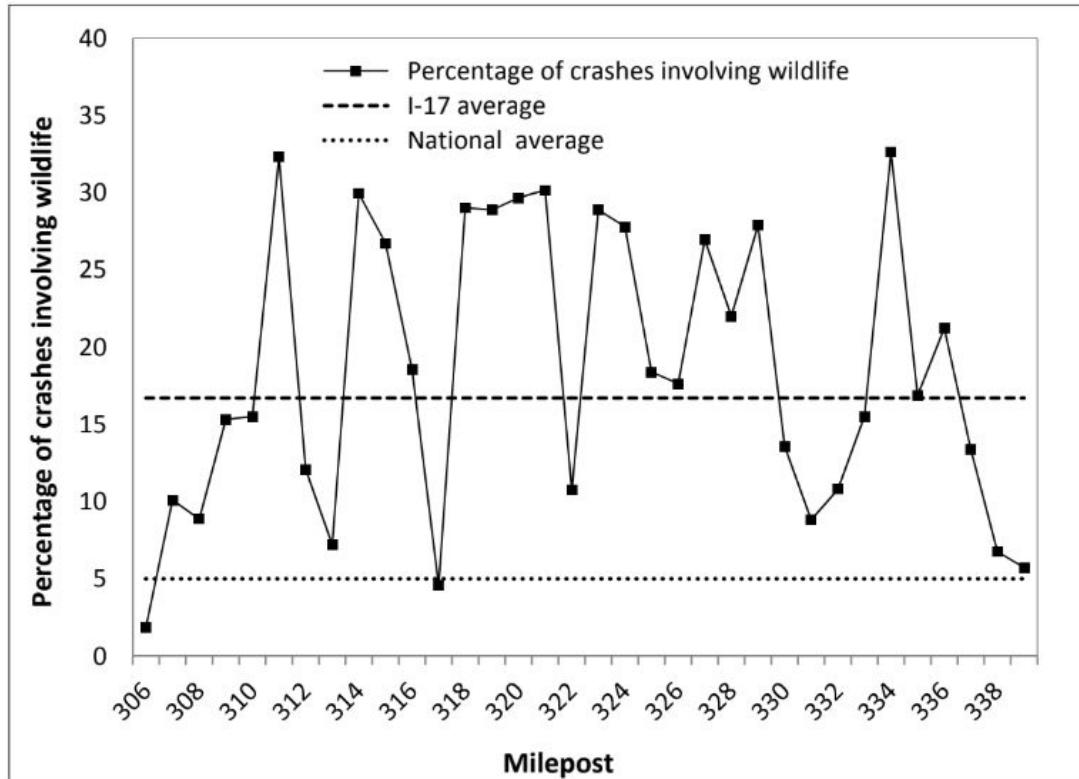


Figure 1. Percentage of Single-vehicle Accidents along I-17 Involving Wildlife from 1994 to 2008 and the National and I-17 (MP 306–339) Averages.

(Note: I-17 data are unpublished by ADOT, national data from Huijser et al. 2008.)

Tracking Wildlife



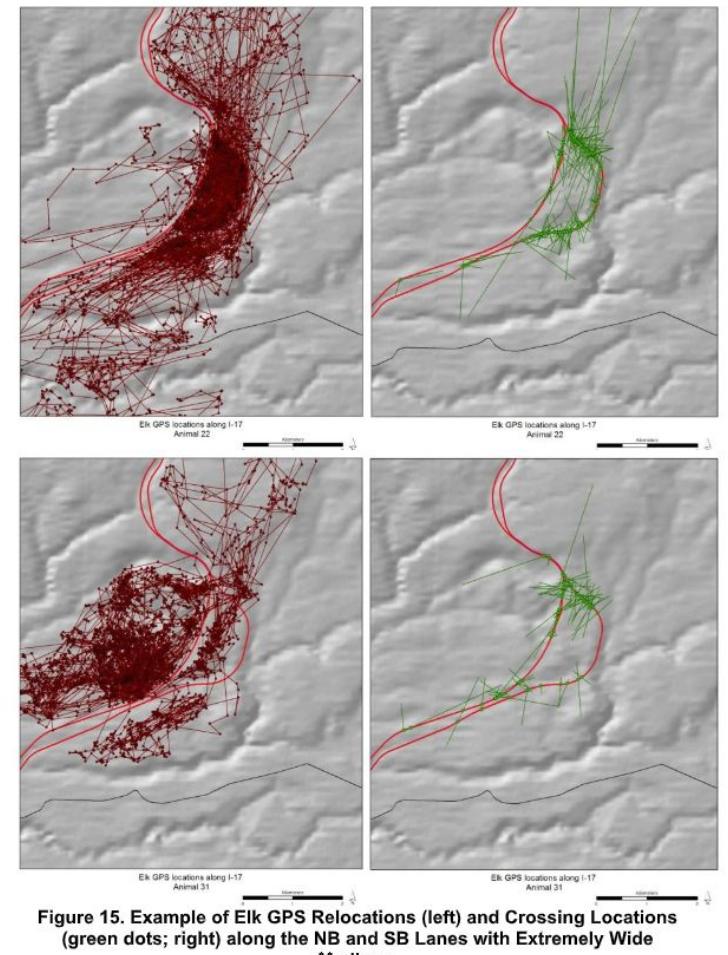
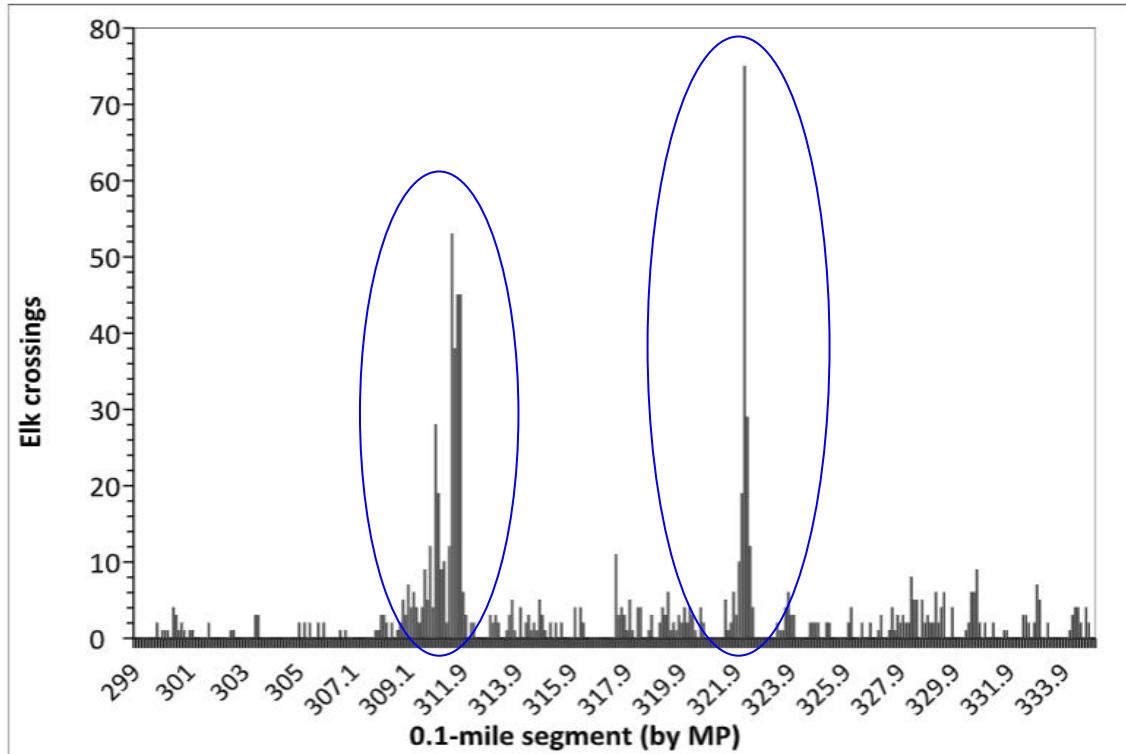


Figure 15. Example of Elk GPS Relocations (left) and Crossing Locations (green dots; right) along the NB and SB Lanes with Extremely Wide Medians.

Elk Movements Associated with a High-traffic Highway: Interstate 17 Final Report 647
ADOT Research Center March 2013

Wildlife Crossing



**Figure 16. Elk Highway Crossing Frequency by 0.1-mi Segment along I-17
Determined from Telemetry, 2006 to 2010.**

*(Note: The two peaks correspond to the extremely wide median location
and area near the Munds Canyon Bridge.)*

Highway Structures

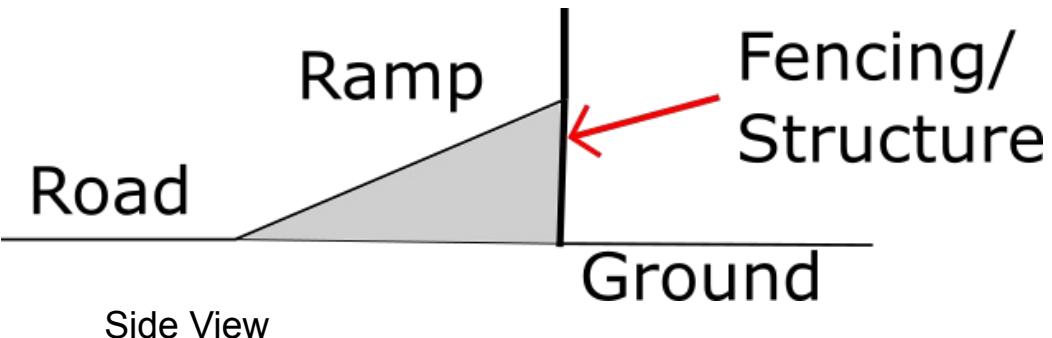
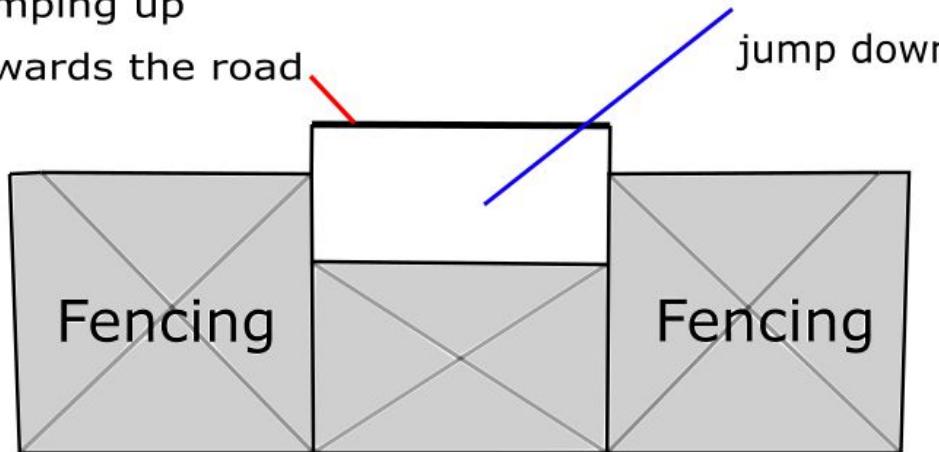


Escape Ramp



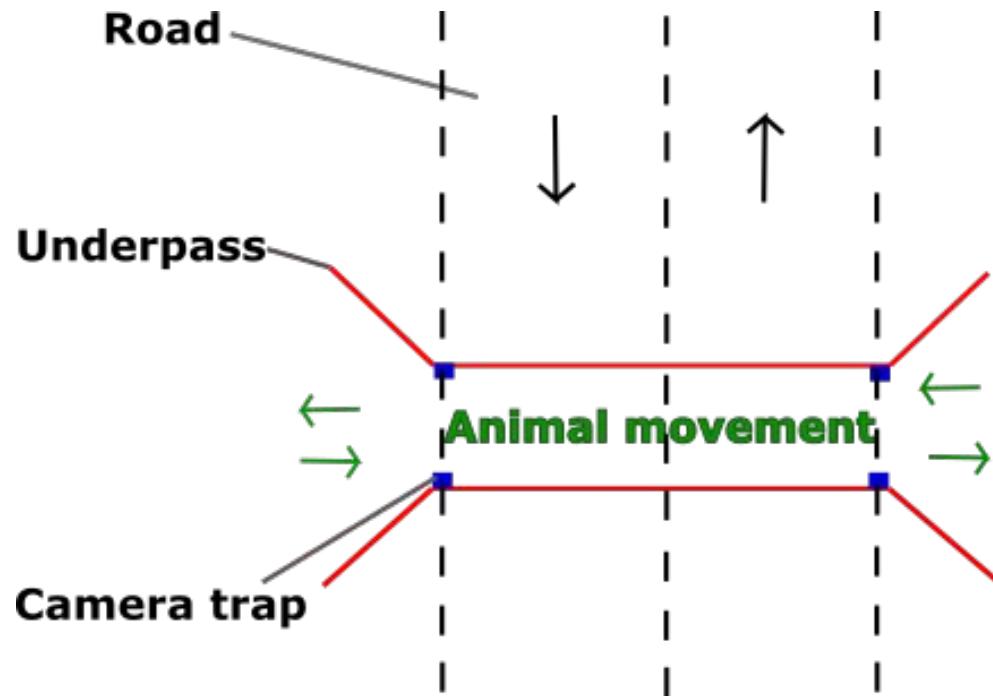
Bar to prevent
animals from
jumping up
towards the road

Space for
animals to
jump down



Ground
Front View

Underpass

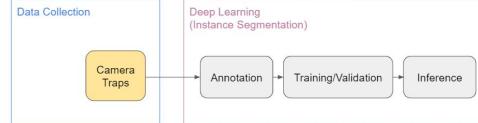
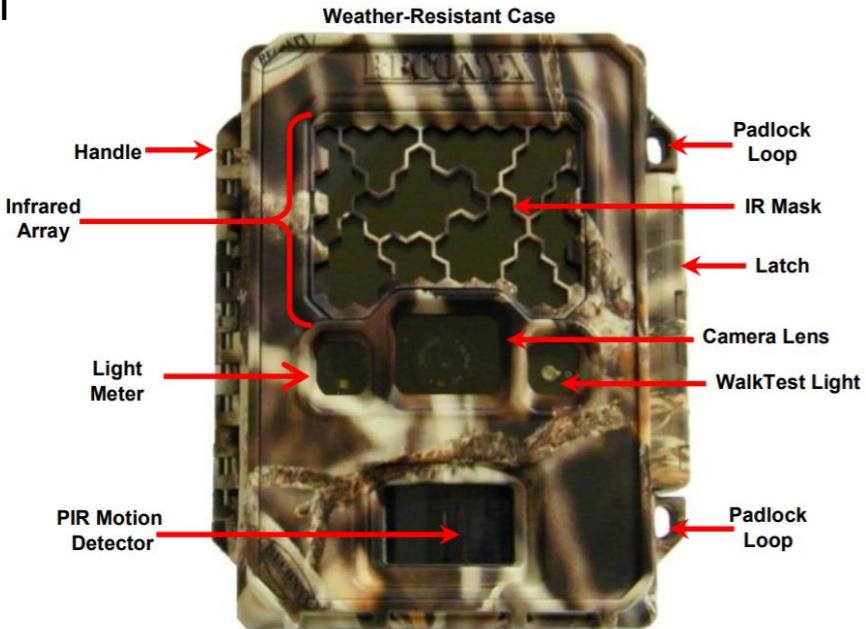


Camera Traps

Reconyx PC800 HyperFire Professional
Semi-Covert Camera Traps

- Motion triggered
- Semi-visible infrared flash
- Color images during the day, black and white images at night
- Sequence of 3-5 images at 2fps

Between 1-9 cameras monitor each structure



Problems/Challenges

- Extremely large data sets
- Wasted storage on blank photos
- Poor image quality
- Inefficient analysis methods
- User-specific bias
- False Negatives



2018-01-21 05:13:28

M 1/3

40 37°F

NM RTN MP452 RCC-1-2



2018-01-21 05:13:29

M 2/3

40 37°F

NM RTN MP452 RCC-1-2



2018-01-21 05:13:30

M 3/3

40 37°F

NM RTN MP452 RCC-1-2



2018-01-21 05:13:38

M 1/3

40 37°F

NM RTN MP452 RCC-1-2



2018-01-21 05:13:39

M 2/3

40 37°F

NM RTN MP452 RCC-1-2



2018-01-21 05:13:40

M 3/3

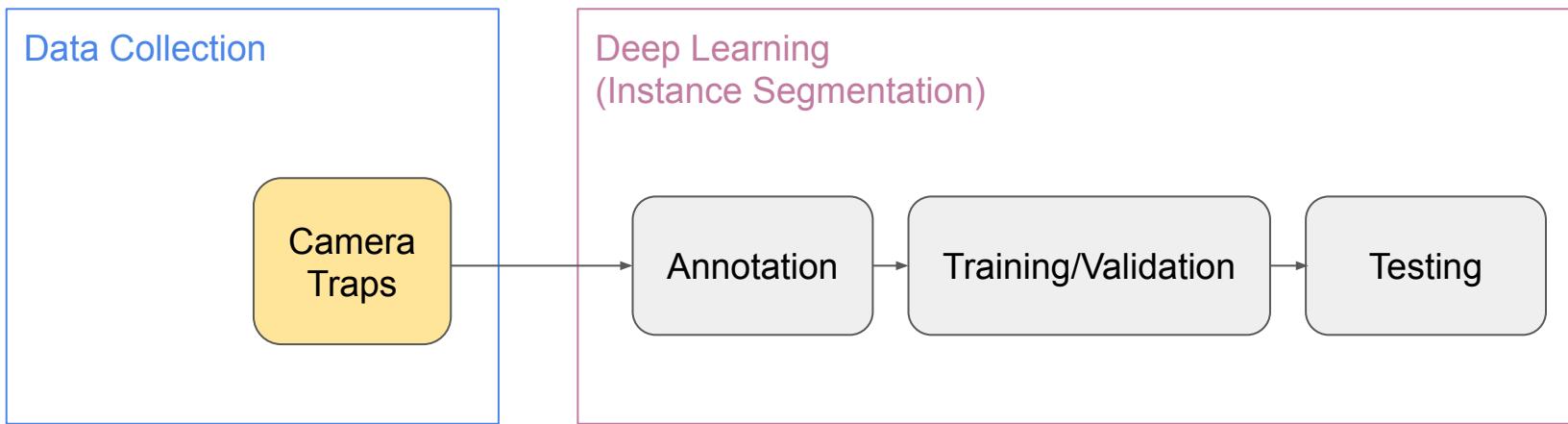
40 37°F

NM RTN MP452 RCC-1-2

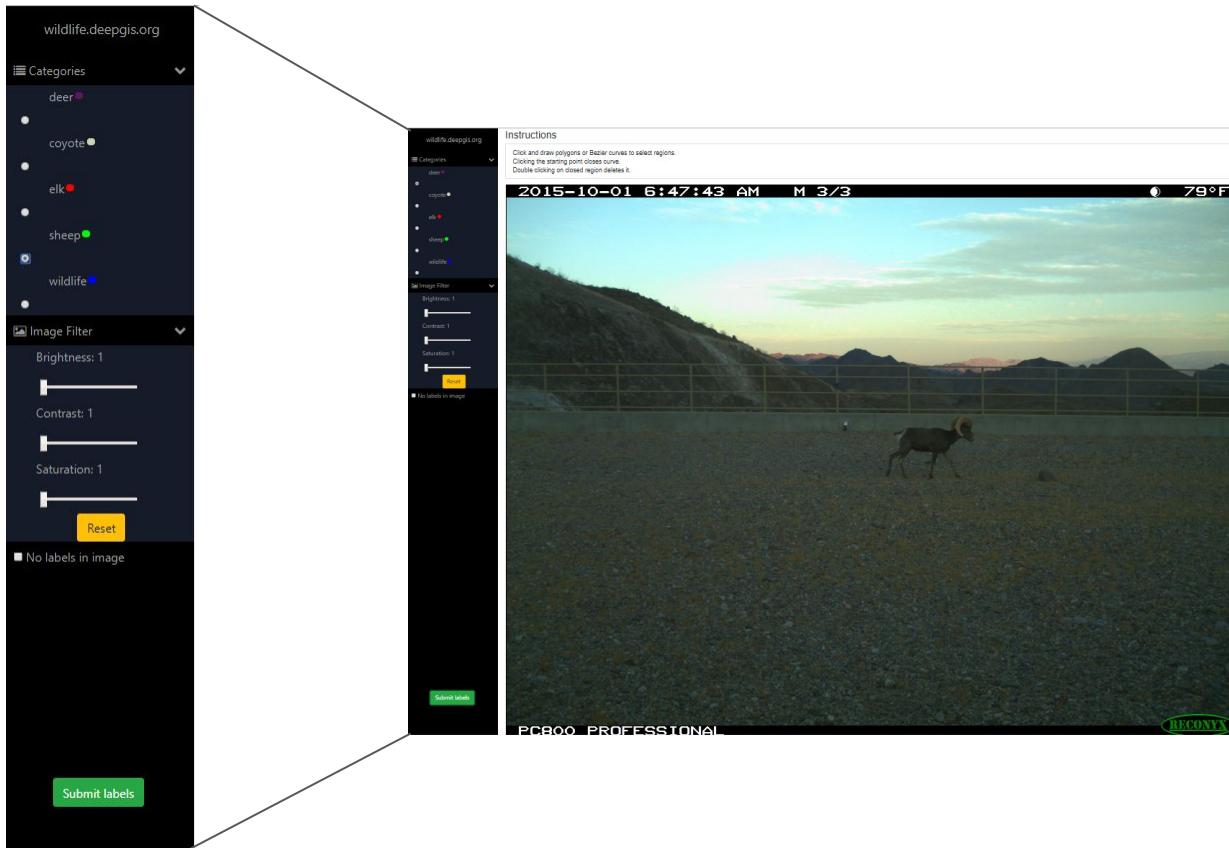
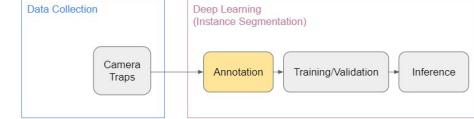


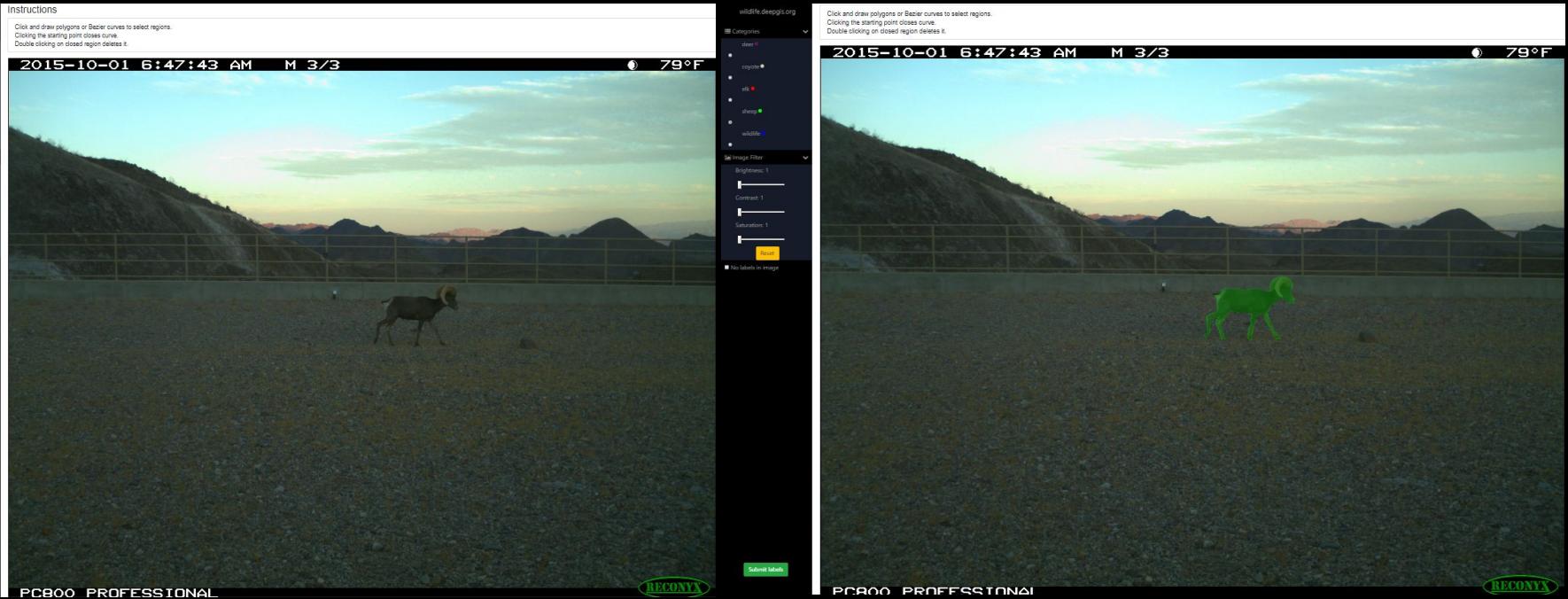
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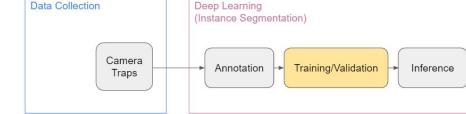


Wildlife - Annotation Tool

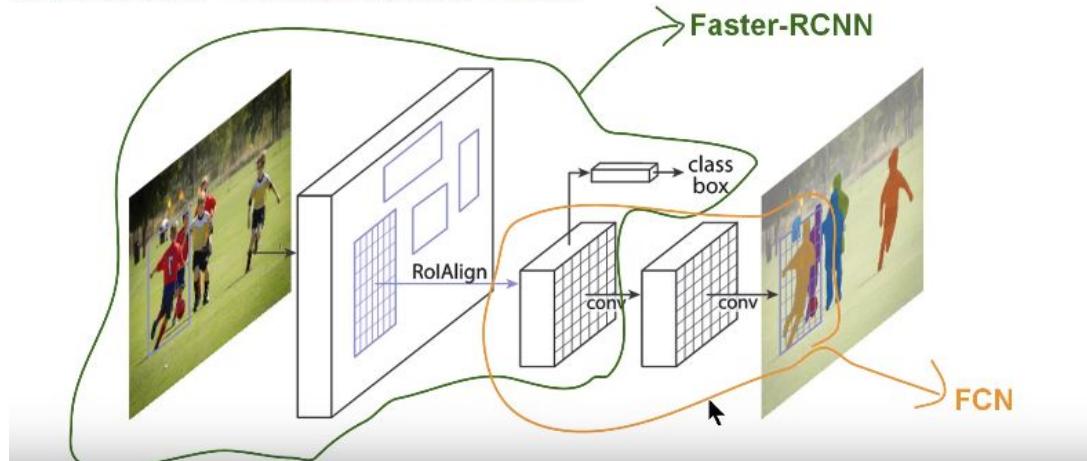




Mask R-CNN



Mask R-CNN → Faster R-CNN + FCN



(He, et al. 2018)

Validation

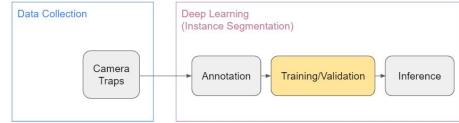


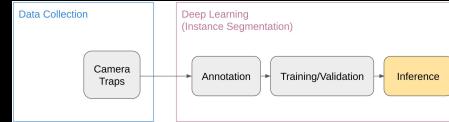
Image #	Original Label	Prediction
0	1 deer	1 elk
1	5 sheep	3 sheep, 1 elk, 1 undetected
2	1 deer	1 deer
3	Blank	Blank
4	2 unlabeled cows	1 deer, 1 elk
5	Blank	Blank
6	1 elk	1 deer
7	2 unlabeled cows	1 deer, 1 undetected
8	1 deer	1 deer
9	1 sheep	1 elk
10	Blank	Blank
11	1 elk	1 elk
12	1 sheep	1 deer
13	Blank	Blank
14	Blank	Blank
15	1 elk	1 deer

- 88% detection accuracy
- 40% classification accuracy

Validation



Testing - Escape Ramp



- 90% detection (18/20)
- 50% classification accuracy (9/18)
- One false positive

Inference - Overpass



- 95% detection (21/22)
- 42% classification accuracy (9/21)
- No false positives

Errors



Interesting Results



Error Due to Training



- 6/9 misclassifications were due to unseen labels (cows or humans)

Future Directions

- improve detection/classification
- increase the number of species
- classify sex/relative age
- track/count individual animals in a sequence of images
- identify direction of travel (did it cross or not cross, coming off the highway or entering the highway)
- use it on video
- use it to verify animal actually present before wasting storage



2017-01-17 04:33:33

M 1/5

33°F



SR260 SJ BF WB

RECONYX

2017-01-17 04:33:34

M 2/5

33°F



SR260 SJ BF WB

RECONYX

2017-01-17 04:33:35

M 3/5

33°F



SR260 SJ BF WB

RECONYX

2017-01-17 04:33:35

M 4/5

33°F



SR260 SJ BF WB

RECONYX

2017-01-17 04:33:36

M 5/5

33°F

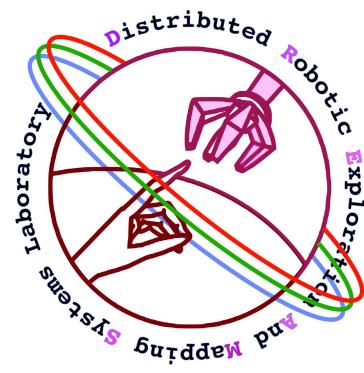


SR260 SJ BF WB

RECONYX

References

- [1] R. Inc., RECOYNYX Hyperfire High Performance Cameras Instruction Manual, RECONYX Inc.
- [2] J. W. Gagnon, C. D. Loberger, S. C. Sprague, K. S. Ogren, S. L. Boe, and R. E. Schweinsburg, “Cost-effective approach to reducing collisions with elk by fencing between existing highway structures,” *Human-Wildlife Interactions*, vol. 9, no. 14, 2015.
- [3] J. Gagnon, N. Dodd, K. Ogren, and R. Schweinsburg, “Factors associated with use of wildlife underpasses and importance of longterm monitoring,” *Journal of Wildlife Management*, vol. 75, no. 6, pp. 1477–1487, 2011.
- [4] K. He, G. Gkioxari, P. Dollar, and R. Girshick, “Mask r-cnn,” *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. PP, no. 99, pp. 1–1, 2018.
- [5] S. W. Chen, S. S. Shivakumar, S. Dcunha, J. Das, E. Okon, C. Qu, C. J. Taylor, and V. Kumar, “Counting apples and oranges with deep learning: A data-driven approach,” *IEEE Robotics and Automation Letters*, vol. 2, no. 2, pp. 781–788, April 2017.



Thank you!

