

# 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



## Data Collection

Camera  
Traps

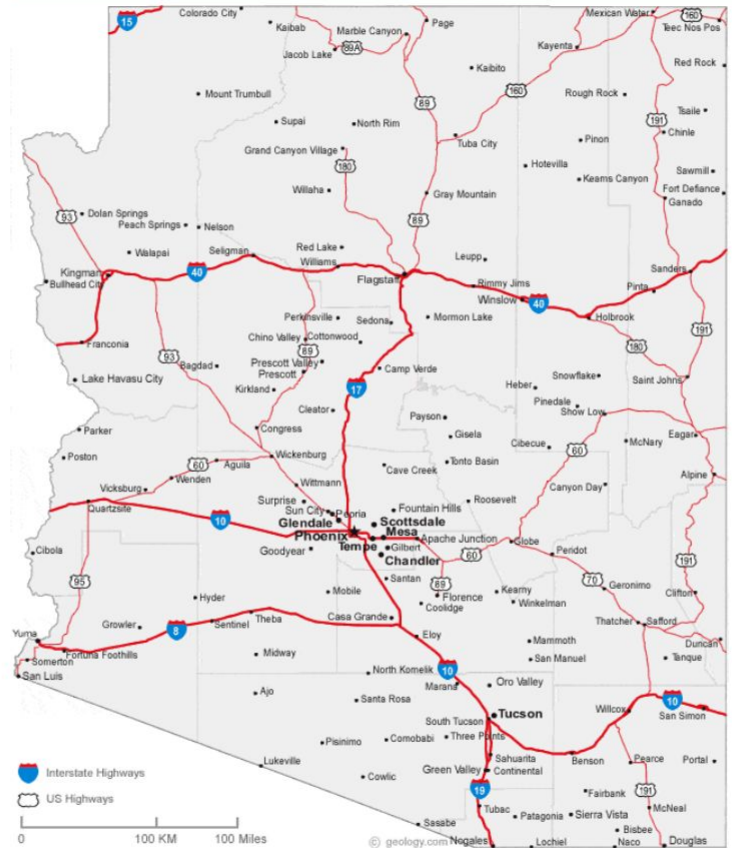
## Deep Learning (Instance Segmentation)

Annotation

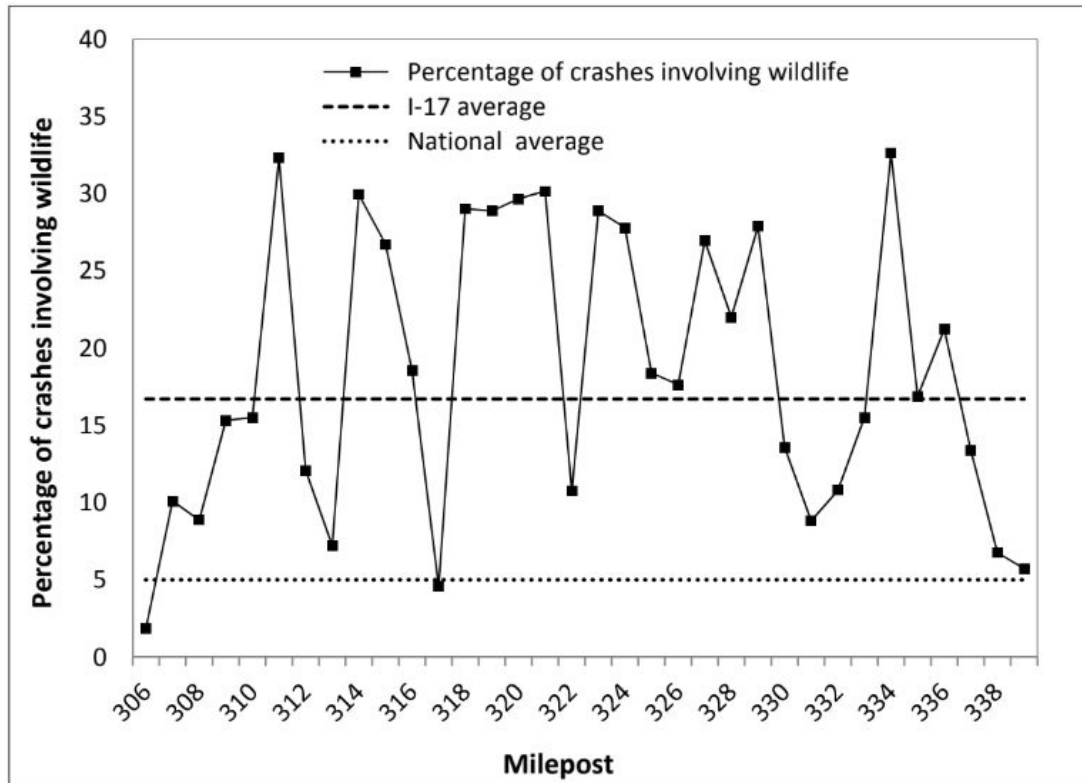
Training/Validation

Testing

# Arizona Highways



# Wildlife-Vehicle Collisions

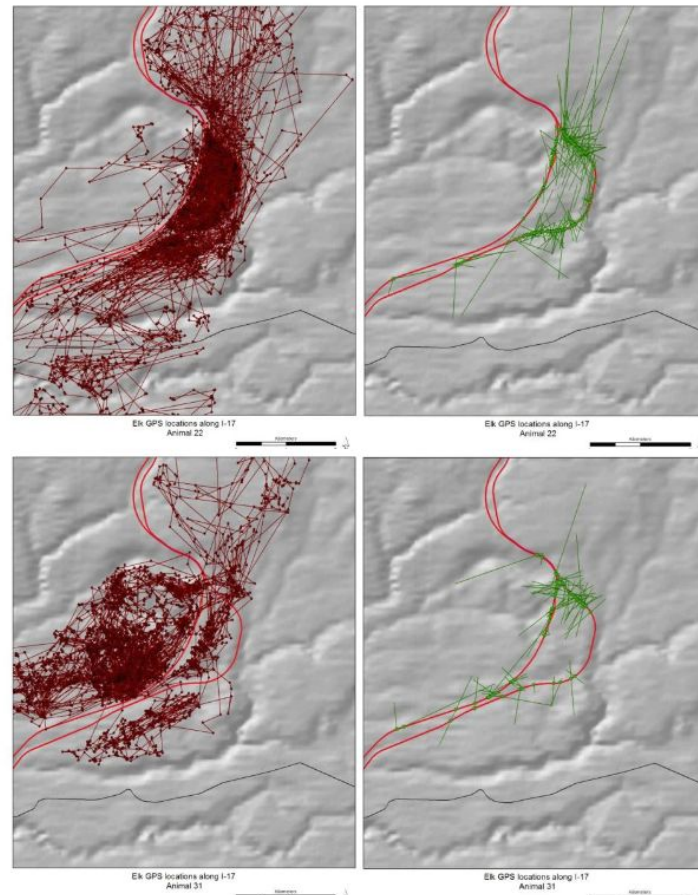


**Figure 1. Percentage of Single-vehicle Accidents along I-17 Involving Wildlife from 1994 to 2008 and the National and I-17 (MP 306–339) Averages.**

*(Note: I-17 data are unpublished by ADOT, national data from Huijser et al. 2008.)*

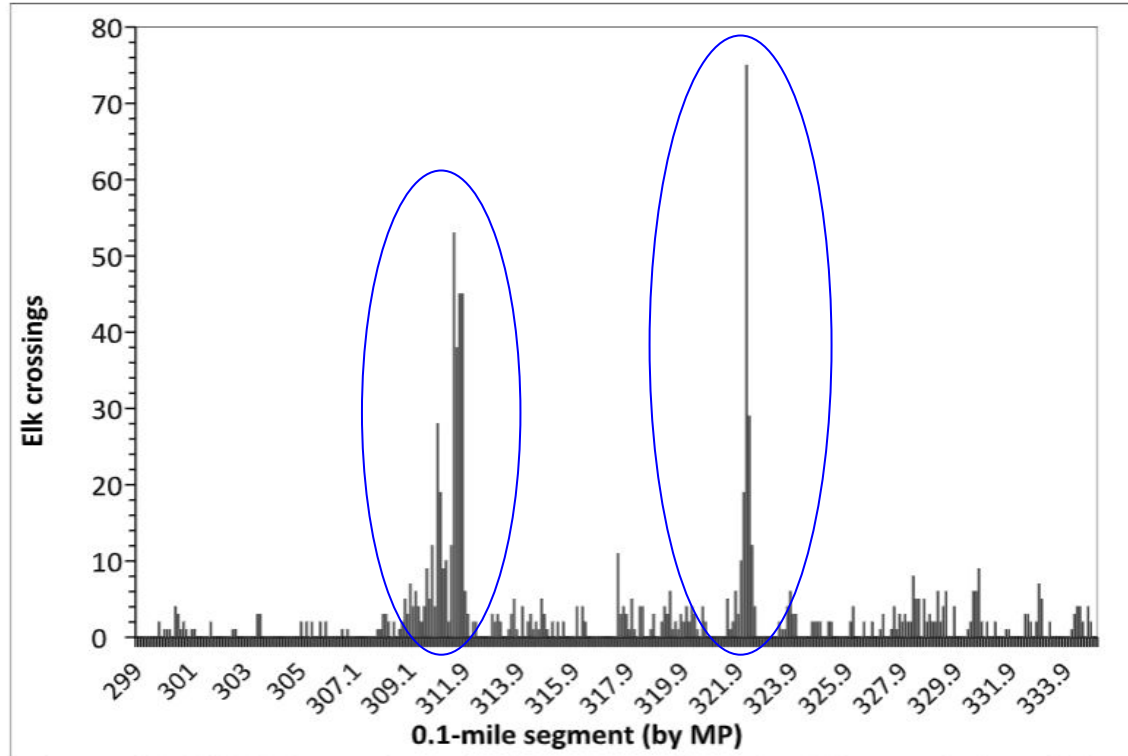
# Tracking Wildlife





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

# 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



US93 JUMP OUT 1.0E



AC MP171.0 EN



SR260 ER IGW



PC800 PROFESSIONAL



SR260 DC6 271.7 WB



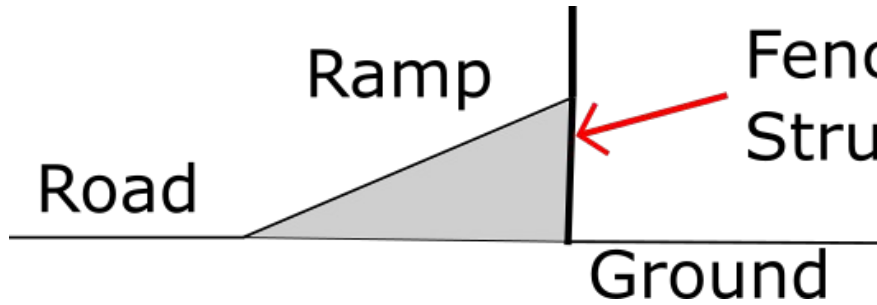
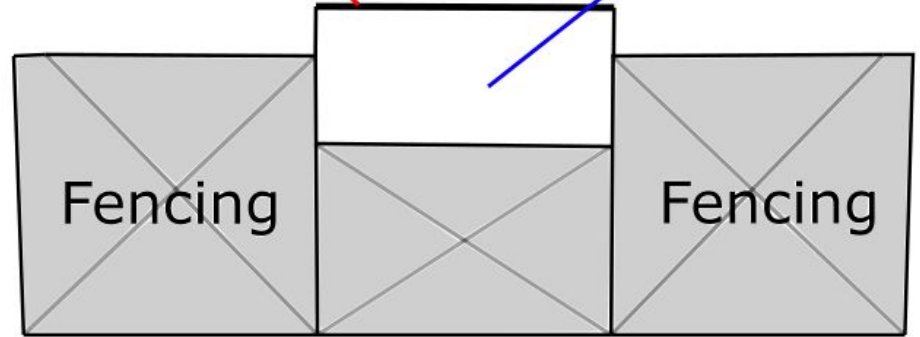
CB MP53.6 2URS

# Escape Ramp



Bar to prevent animals from jumping up towards the road

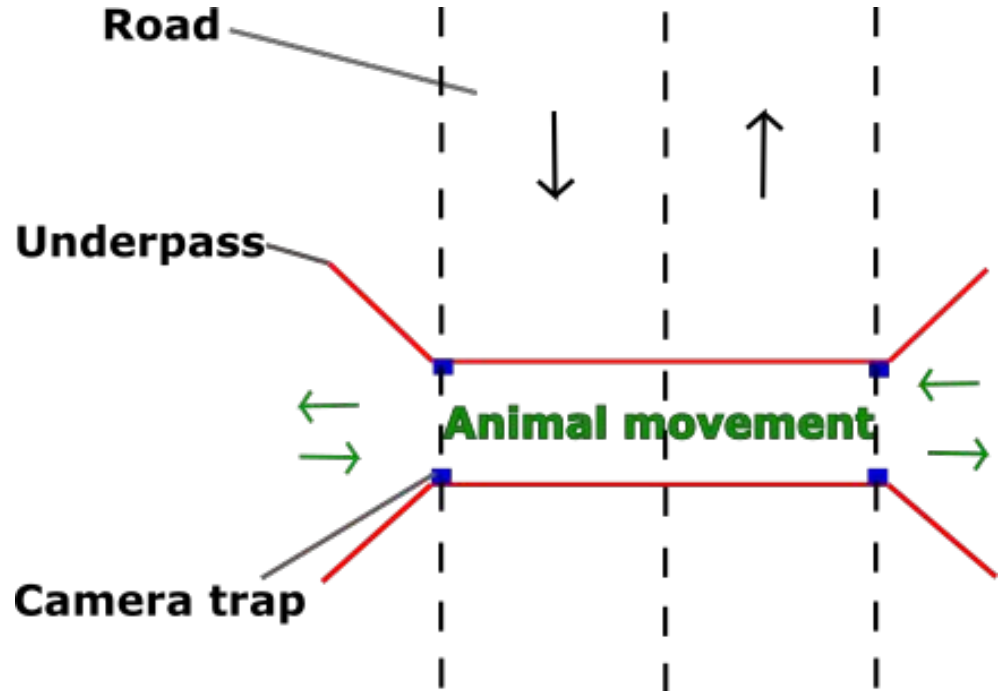
Space for animals to jump down



Ground  
Front View

Side View

# Underpass

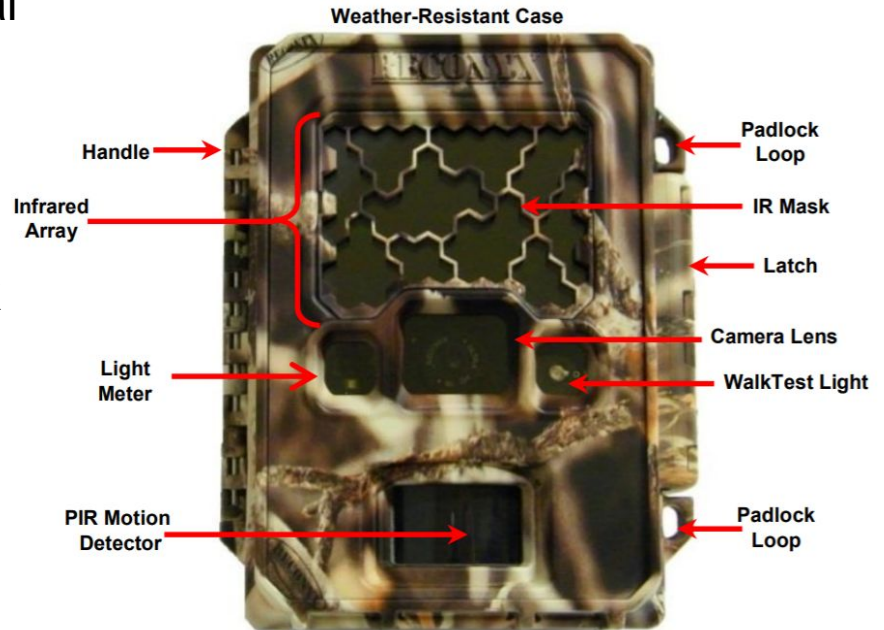
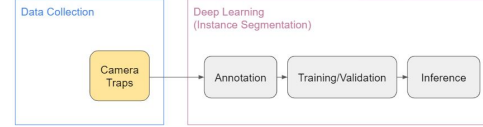


# Camera Traps

## 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

30 37°F

NM RTN MP452 RCC-1-2



2018-01-21 05:13:29

M 2/3

37°F

NM RTN MP452 RCC-1-2



2018-01-21 05:13:30

M 3/3

30 37°F

NM RTN MP452 RCC-1-2





2018-01-21 05:13:38

M 1/3

30 37°F

NM RTN MP452 RCC-1-2



2018-01-21 05:13:39

M 2/3

30 37°F

NM RTN MP452 RCC-1-2



2018-01-21 05:13:40

M 3/3

30 37°F

NM RTN MP452 RCC-1-2



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## Data Collection

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Traps

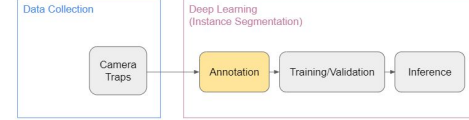
## Deep Learning (Instance Segmentation)

Annotation

Training/Validation

Testing

# Wildlife - Annotation Tool



### Instructions

Click and draw polygons or Bezier curves to select regions.  
Clicking the starting point closes curve.  
Double clicking on closed region deletes it.

#### Categories

- deer
- coyote
- cat
- sheep
- wildlife

#### Image Filter

Brightness: 1

Contrast: 1

Saturation: 1

Done

No labels in image

2015-10-01 6:47:43 AM M 3/3 79°F



Submit Labels

PC800 PROFESSIONAL



Click and draw polygons or Bezier curves to select regions.  
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#### Categories

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2015-10-01 6:47:43 AM M 3/3 79°F

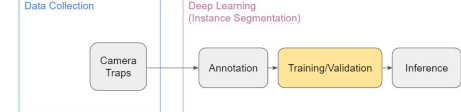


Submit Labels

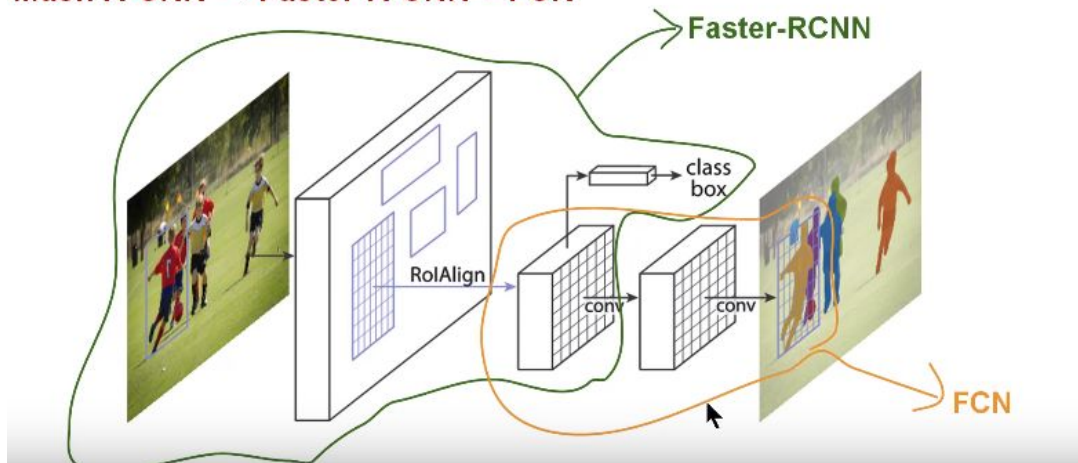
PC800 PROFESSIONAL



# MaskRCNN

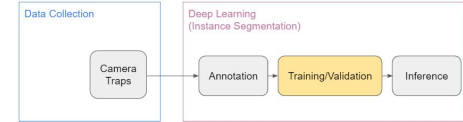


Mask R-CNN → Faster R-CNN + FCN



(He, et al. 2018)

# Validation

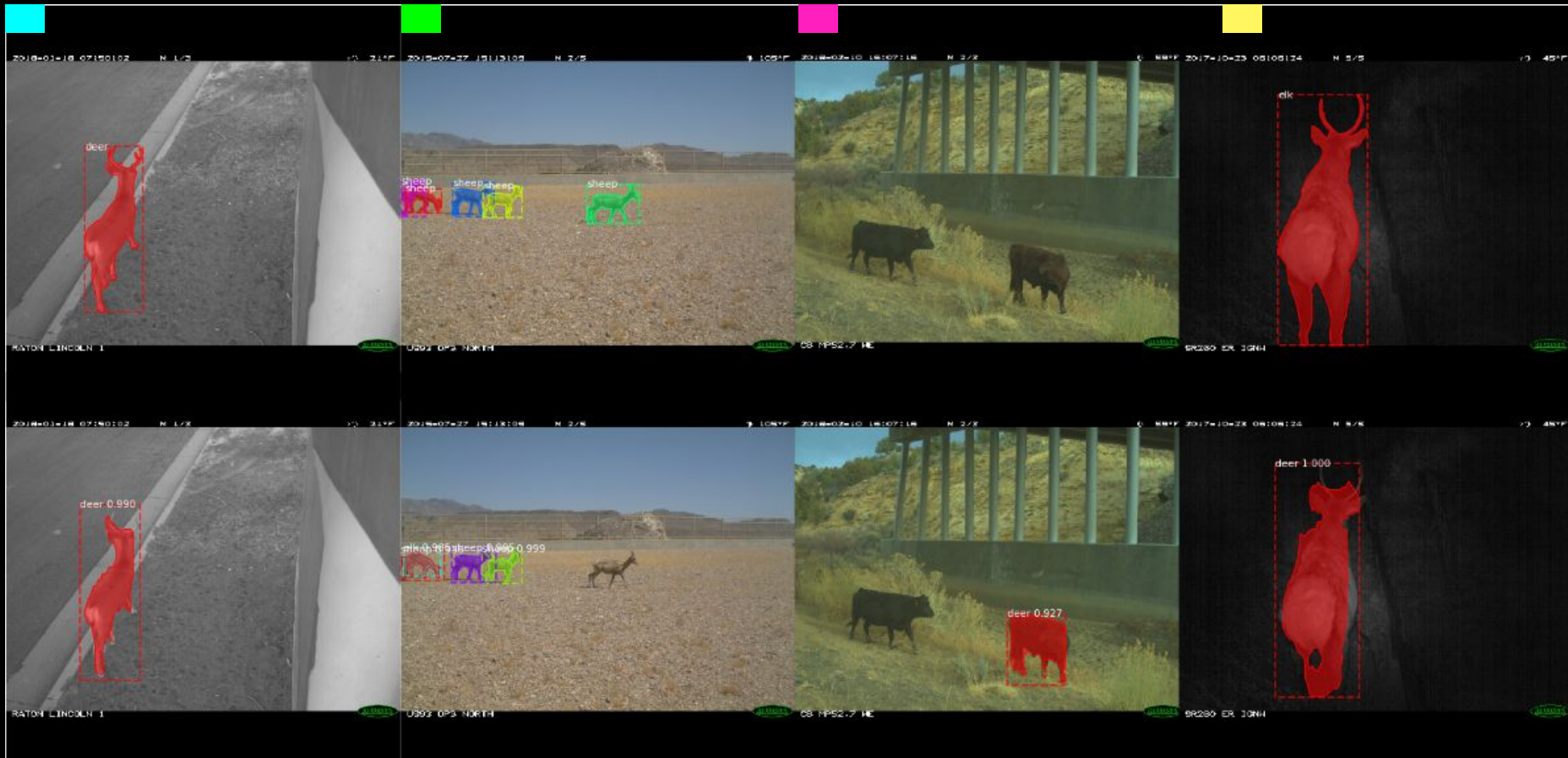


| Image # | Original Label   | Prediction                   |
|---------|------------------|------------------------------|
| 0       | 1 deer           | 1 elk                        |
| 1       | 5 sheep          | 3 sheep, 1 elk, 1 undetected |
| 2       | 1 deer           | 1 deer                       |
| 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                       |

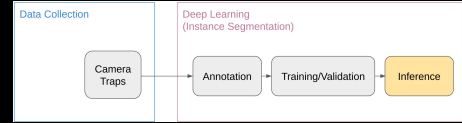
- 88% detection accuracy
- 40% classification accuracy



# 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



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



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

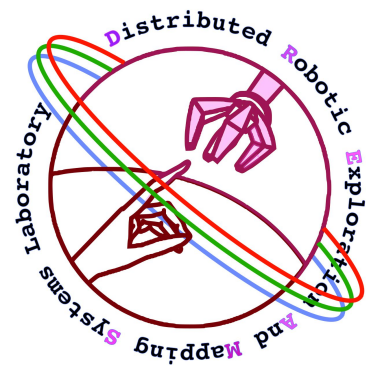


SR260 SJ BF WB



# 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.



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Thank you!

