

Counting Elephants in Aerial Images

Semi-Automated Aerial Surveying of Elephants using Deep Neural Networks

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Problem Statement

- ▶ Aerial surveying is one of the most popular methods for determining the size of an animal population
- ▶ Tracking population size is critical to detect problems and respond accordingly
- ▶ Still conducted using human observers – costly, hence performed infrequently
- ▶ Using high resolution cameras and advances in computer vision, the goal was to build a new method that has:
 - ▶ Improved accuracy, and precision which is consistent
 - ▶ Lower overall survey cost
 - ▶ A permanent geo-referenced record
 - ▶ Ability to map additional features – erosion, infrastructure

Elephant Survey System – Brief History

- ▶ Paul Maritz chooses to sponsor development of an automated system.
- ▶ Approaches iKubu in early 2014.
- ▶ iKubu develops camera rig for use in BushCat LSA, as well as data acquisition software and an early version of the elephant detection software.
- ▶ iKubu gets acquired by Garmin in late 2014, from which point Innoventix continues the work.
- ▶ Innoventix has redone the detection pipeline and executed multiple trials with the system.



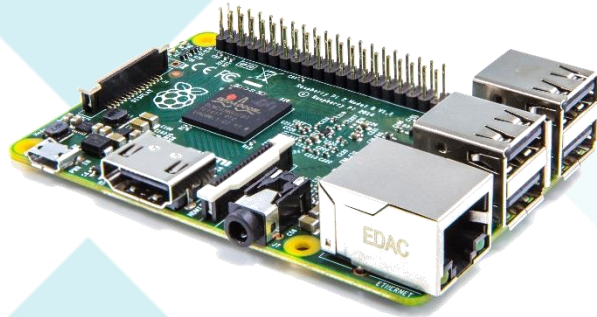


TruSense Laser Altimeter – provides accurate low altitude readings



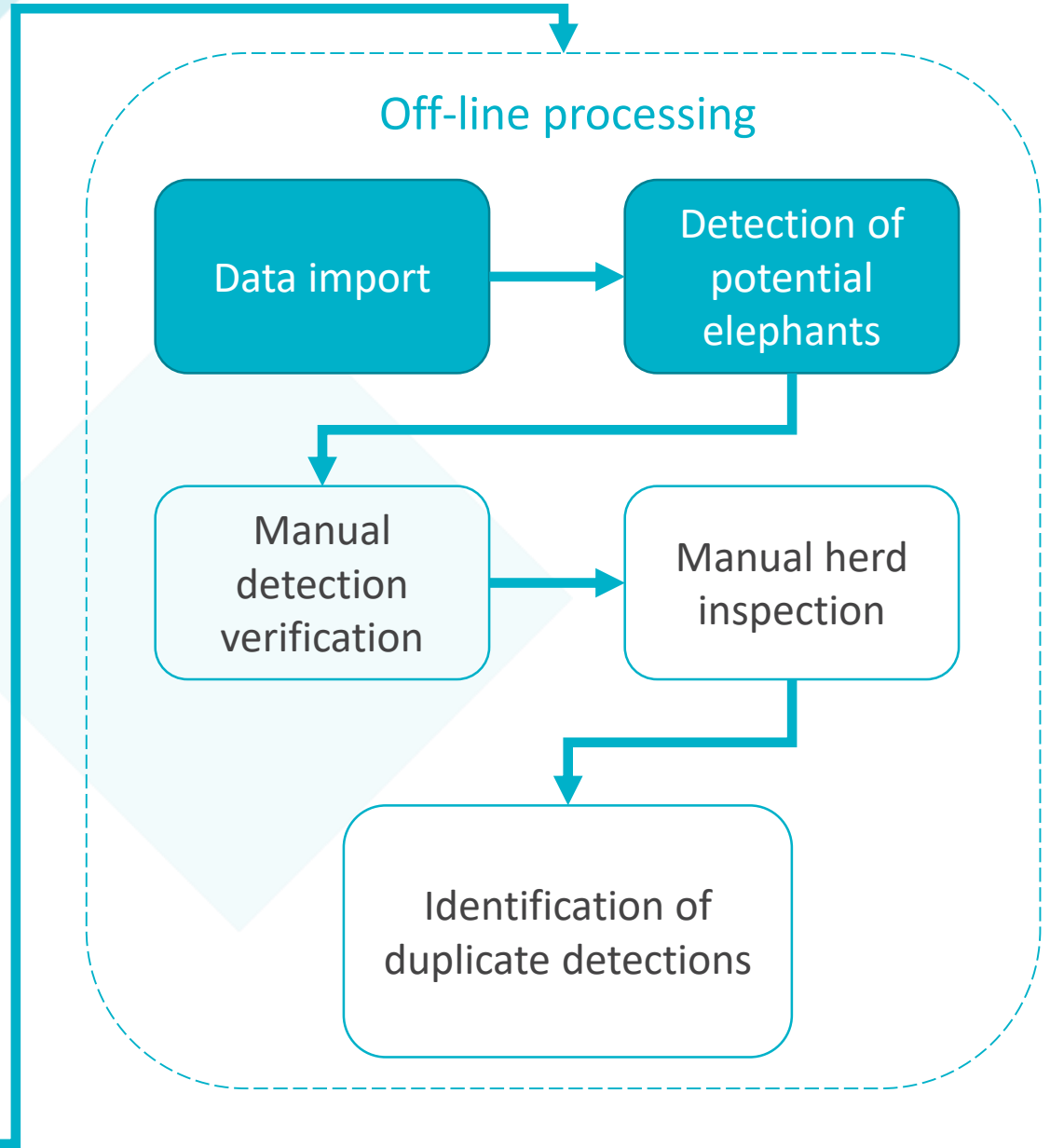
Canon 6D EOS Cameras

Images and GPS coordinates

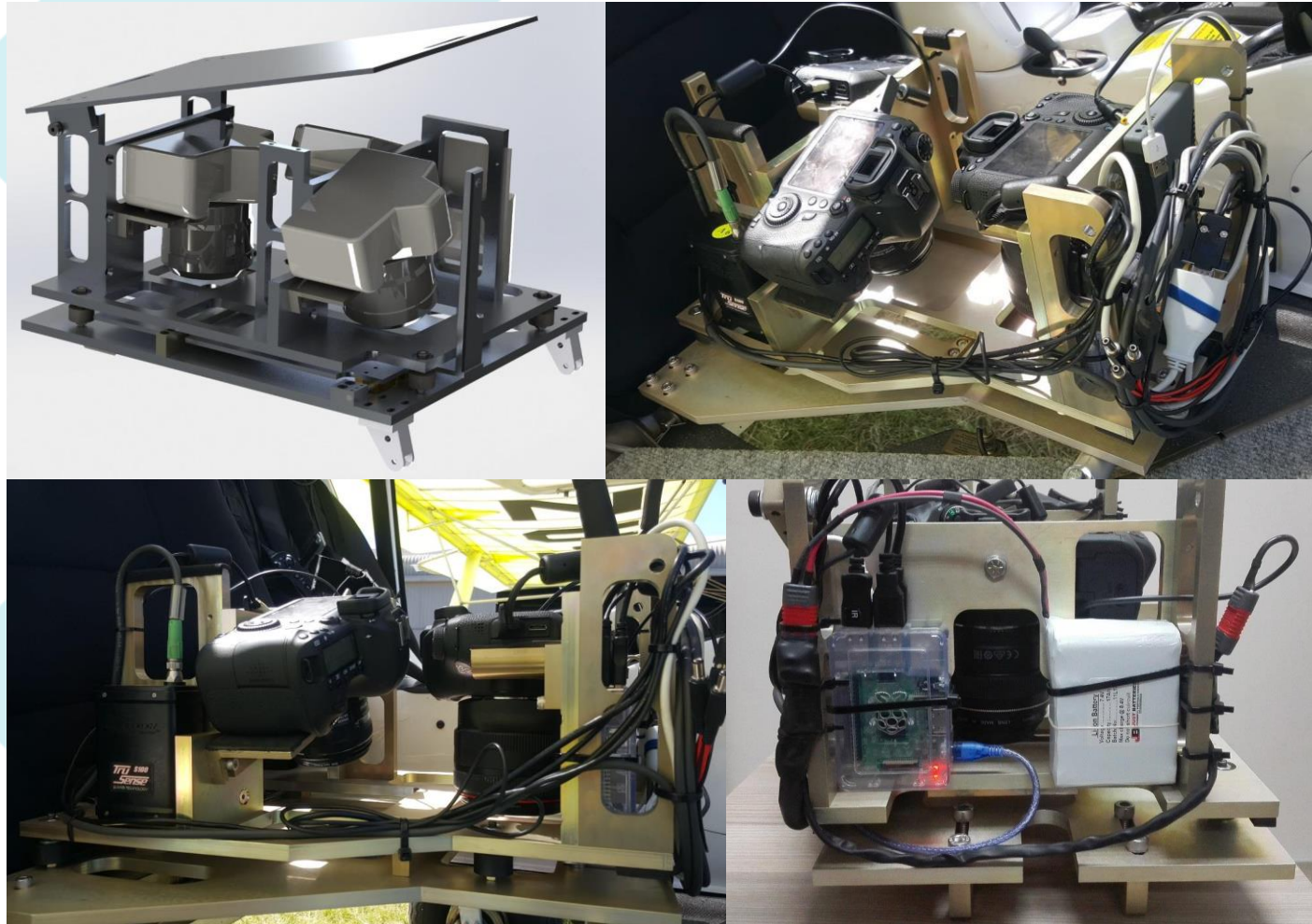


Raspberry Pi Computer – control sensor capture rates

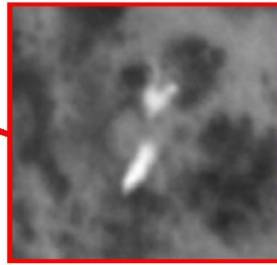
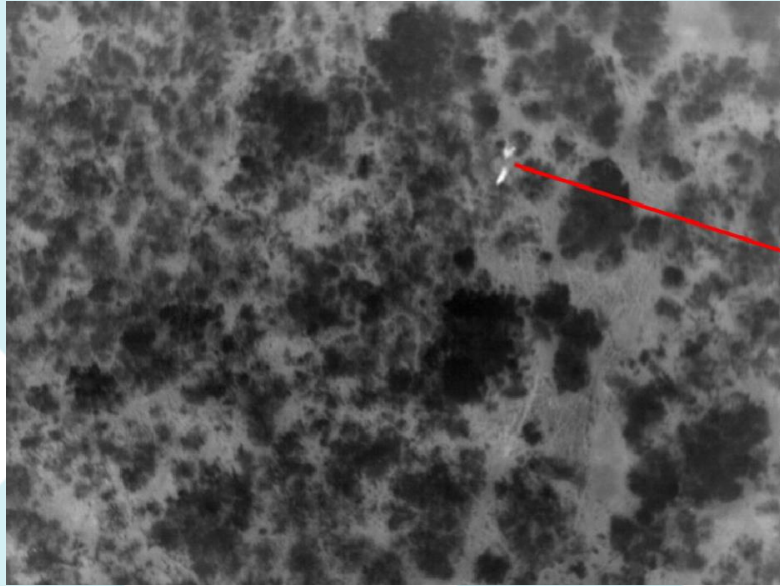
Altitudes, configuration information and logs



ESS Capture rig



ESS – Original detection pipeline



Deep Learning

- ▶ Deep learning is the application of artificial neural nets with more than a single hidden layer to machine learning problems.
- ▶ The field of deep learning gained prominence with the celebrated victory of AlexNet at ILSVRC 2012.
- ▶ Deep learning has completely dominated every other approach to machine vision tasks, from classification, through detection, description and even visual question answering.
- ▶ It is also making rapid progress in other fields, such as speech recognition, natural language processing and unsupervised learning..



Example output of the model

Elephant detection method

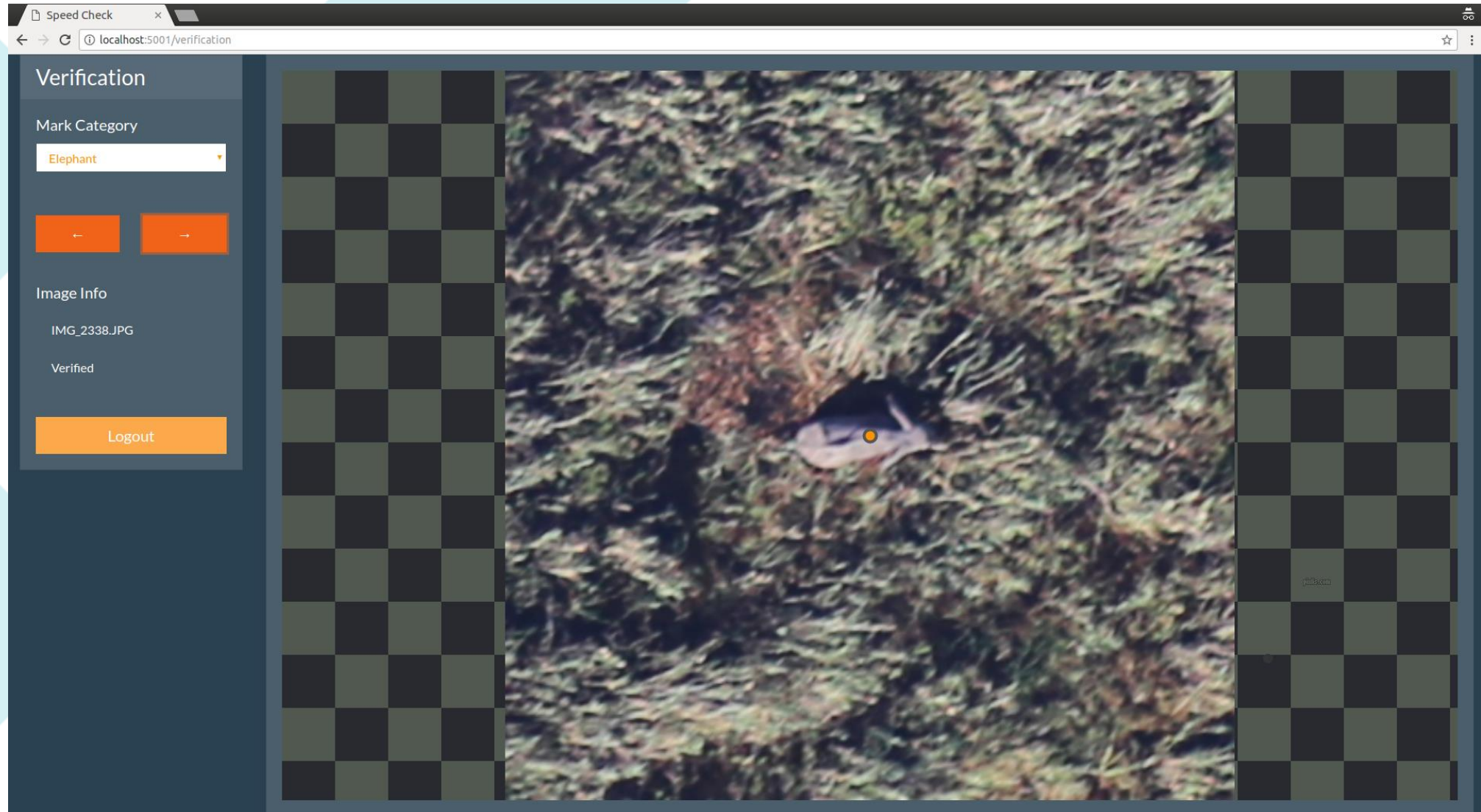
- ▶ Adapted a deep learning classifier network (VGG, MobileNet) to have only two output classes (background/elephant) and to be fully convolutional
- ▶ Retrained it using database of images and elephant locations
 - ▶ 97 000 images with 9 500 elephants
- ▶ Network is then applied to an image to produce a 'heatmap' showing the locations likely to contain elephants



Verification

- ▶ Even with a classifier that has a very low false alarm rate, there can still be a high number of false alarms because:
 - ▶ Images are high resolution – 20MP
 - ▶ A lot of images are collected during a survey flight – 10 000 for a typical 4 hour flight
- ▶ Our verification tool allows multiple users to quickly review the most likely locations – rejecting them or marking any elephants found
- ▶ Not completely labour free, but vastly reduced the amount of imagery to search through

Detection Verification



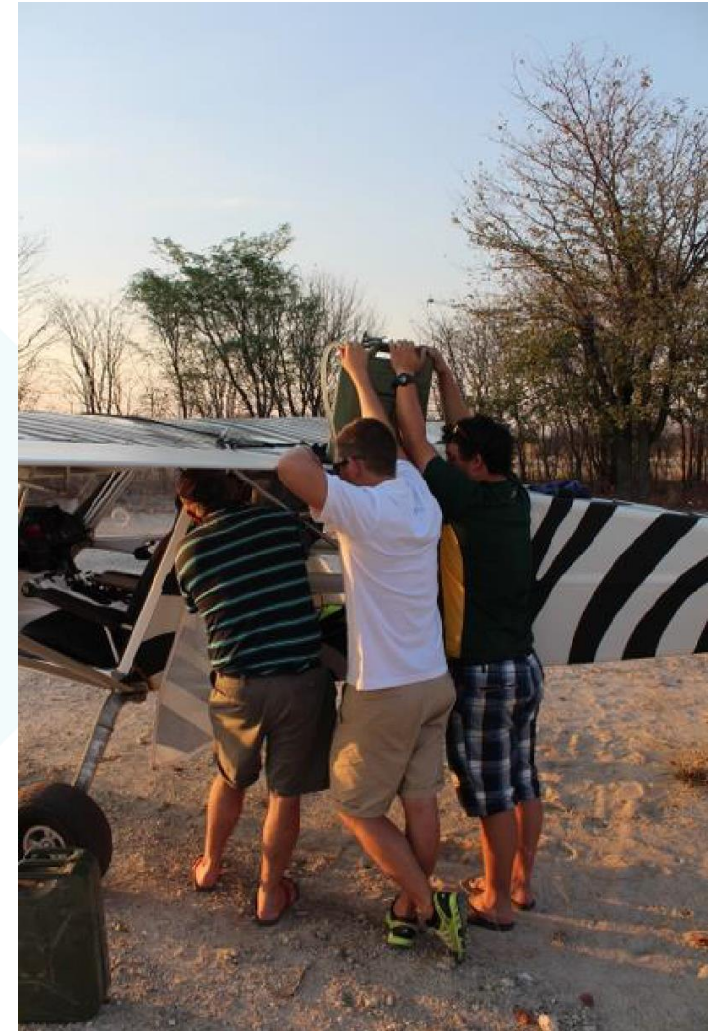
Field work

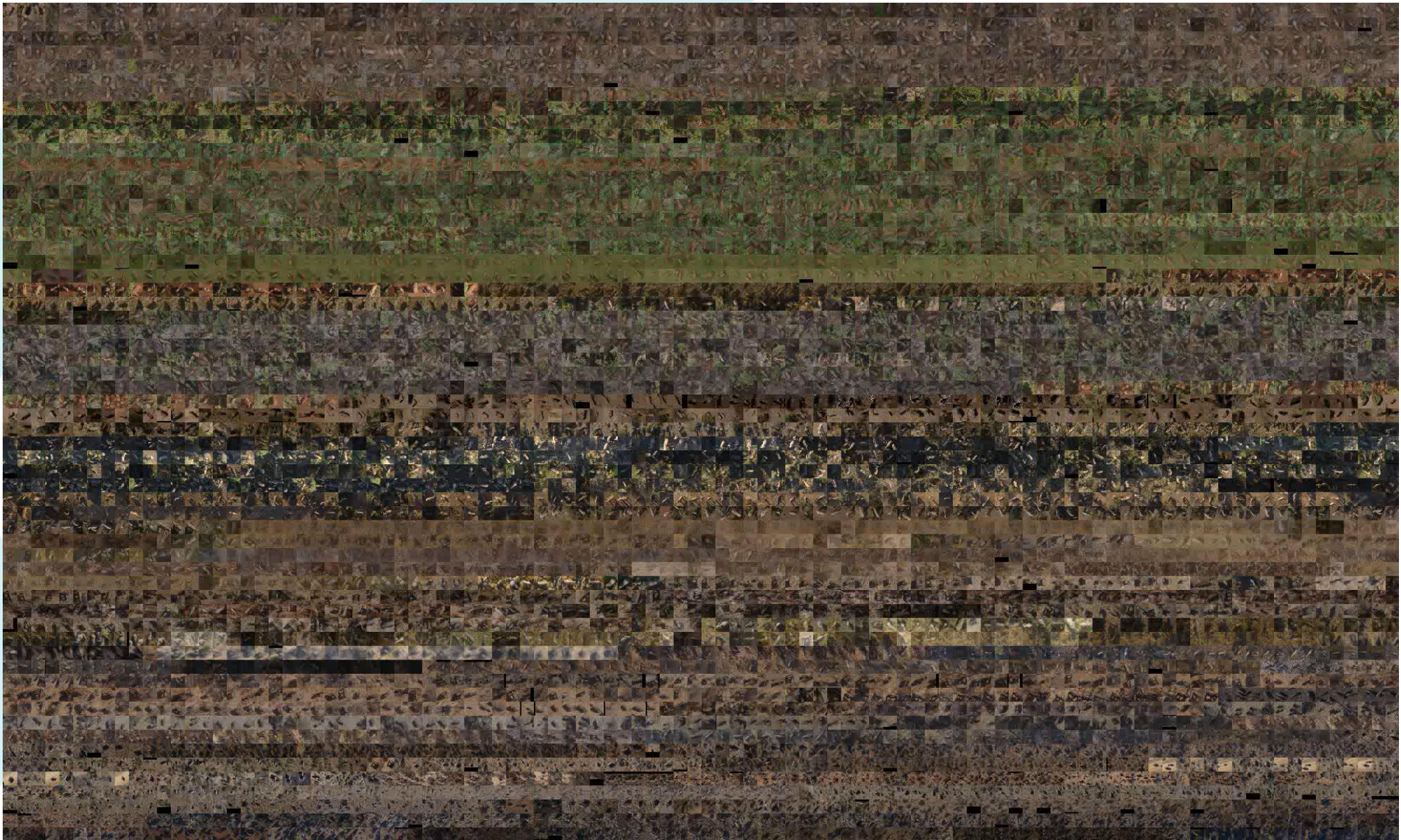
Data gathering has taken place in:

- ▶ Zulu Nyala Private game reserve (SA)
- ▶ Phinda private Game reserve (SA)
- ▶ Northern Tuli Game reserve (Botswana)
- ▶ NG26 Concession (Botswana)
- ▶ Madikwe Game reserve (SA)
- ▶ Bwabwata and Mudumu game reserves (Namibia)
- ▶ Etosha Heights Game reserve (Namibia)

Gathered dataset:

- ▶ 96 837 images covering an estimated 720 000 hectares
- ▶ 1077 images containing known elephants
- ▶ >95 000 background images characterising a wide range of natural backgrounds
- ▶ 9545 elephant images of which 6786 are nominally unique



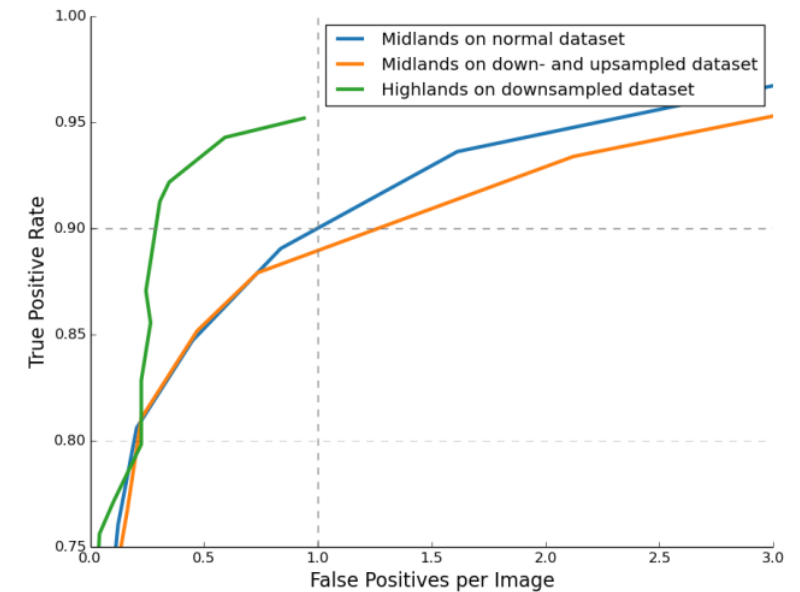


ESS – Comparative statistics

	Traditional	ESS
Recommended search rate	< 1.5 km ² /min	3.25 km ² /min
Crew	4	1
Aerial platform	4-6 seater	2-seater
Accuracy	Worse?	Better?

ESS – How well does it work?

- ▶ Quantitative evaluation of the ESS has always been a challenge
- ▶ Main problem is that we do not have a reliable source of ground truth
- ▶ No satisfying solution -> Rephrase the question

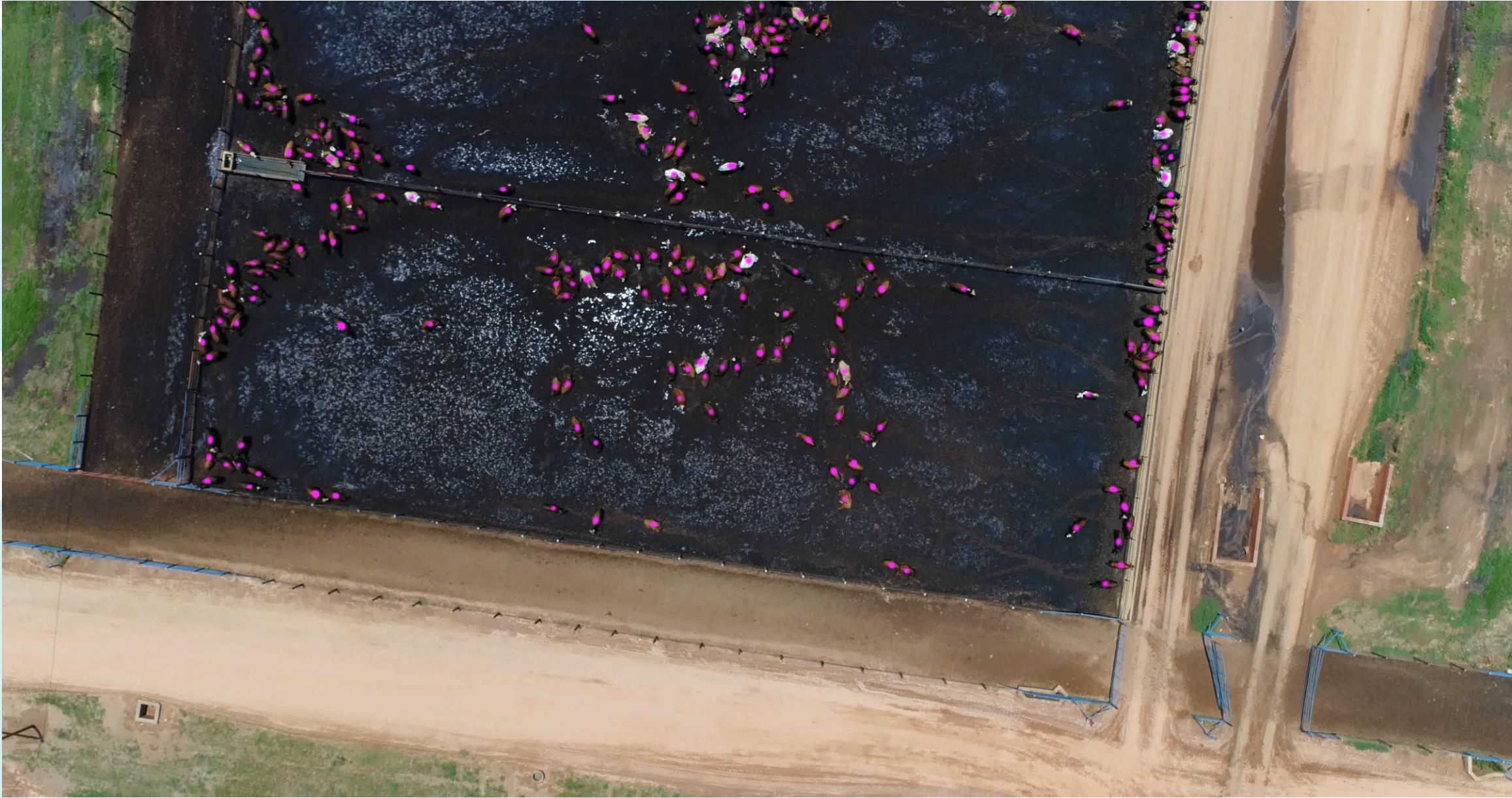


Comparison to human crew

- ▶ Recently completed a comparison exercise with an aerial survey crew in Botswana. Pseudo direct comparison:
 - ▶ Inspect same areas but with time gap of up to 30 minutes
 - ▶ ESS found 588 of 605 elephants spotted by the human crew
 - ▶ Error rate of 3% on total elephants
 - ▶ ESS found a total of 1665 elephants (due to larger search width)
 - ▶ After normalisation ESS found 2% more elephants in total
- ▶ Very encouraging result, however too small a difference and too small a sample to be statistically significant

Conclusions / Future work

- ▶ Results indicate that the ESS performs well relative to a human counting crew, at much lower cost
- ▶ We are arranging additional comparative surveys to increase confidence in findings
- ▶ Looking to adapt the system to other species



Thank You!