University of BRISTOL

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INTERNATIONAL

PERSPECTIVES

IN ANIMAL BIOMETRICS

MULTI-SEMANTIC

Species, Traits, Individuals, Pose, Context, Behaviours

DATA DRIVEN

AI Taxonomics, Open Set Recognition

ROBOTIC

Integrated Active Monitoring Concepts

STANDARDISED

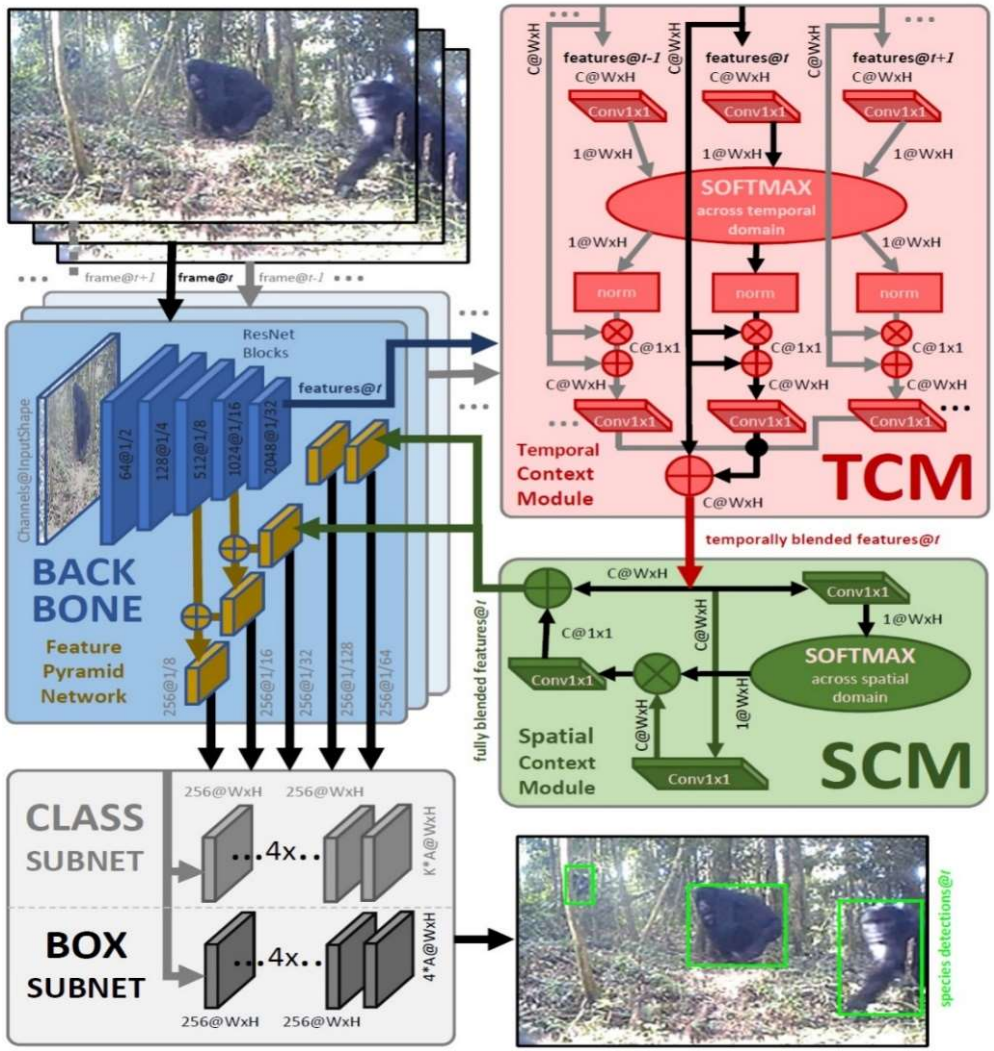
Large Scale Datasets, AI Components, and Platforms

Acknowledgements: W Andrew, X Yang, T Karaderi, D Schmidt, A Hsiang, B Hughes, H Kuehl, C Greatwood, A Dowsey, J Gao, M Xue, C Brust, J Denzler, M Mirmehdi, NW Campbell, O Brookes, F Sakib, AS Crunchant, M Egerer, A Loos, K Zuberbuehler, K Corogenes, V Leinert, L Kulik, M Groenenberg, C Kaeding, M Manguette

15 Slides

Visual Animal Detection in Challenging Settings

Spatial+Temporal Attention Components



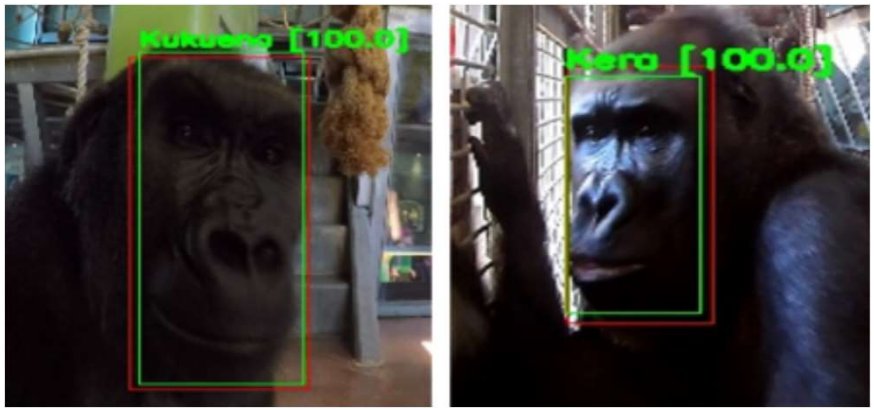
X Yang, M Mirmehdi, T Burghardt. **Great Ape Detection in Challenging Jungle Camera Trap Footage via Attention-Based Spatial and Temporal Feature Blending.** *Computer Vision for Wildlife Conservation (CVWC) Workshop at IEEE International Conference of Computer Vision (ICCVW),* pp. 255-262, 2019. (DOI:10.1109/ICCVW.2019.00034), (CVF Version), (Arxiv PDF), (Dataset PanAfrican2019 Video), (Dataset PanAfrican2019 Annotations and Code)

Attention-highlighted Locations related to Species Signal

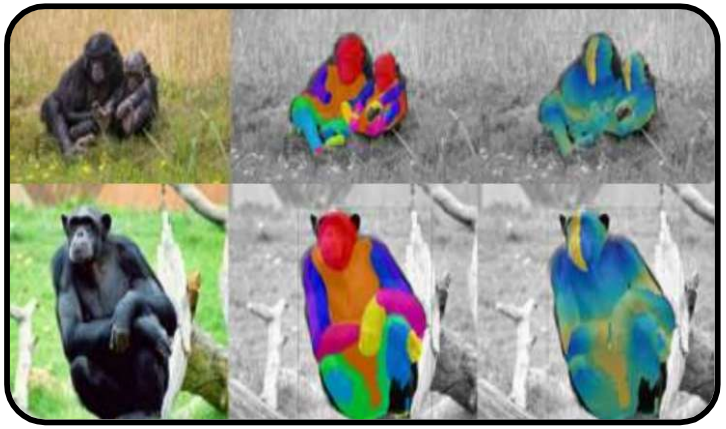
(videos © PanAfrican Programme)

(videos © PanAfrican Programme)

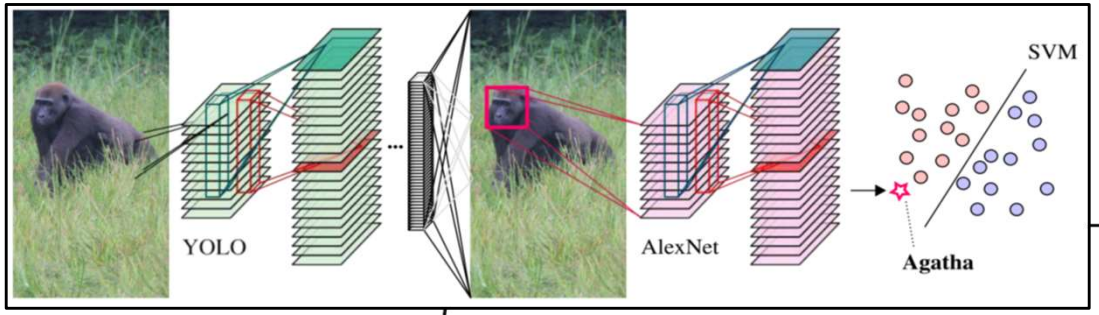
More Great Ape Examples: Identity, Traits and Body Pose



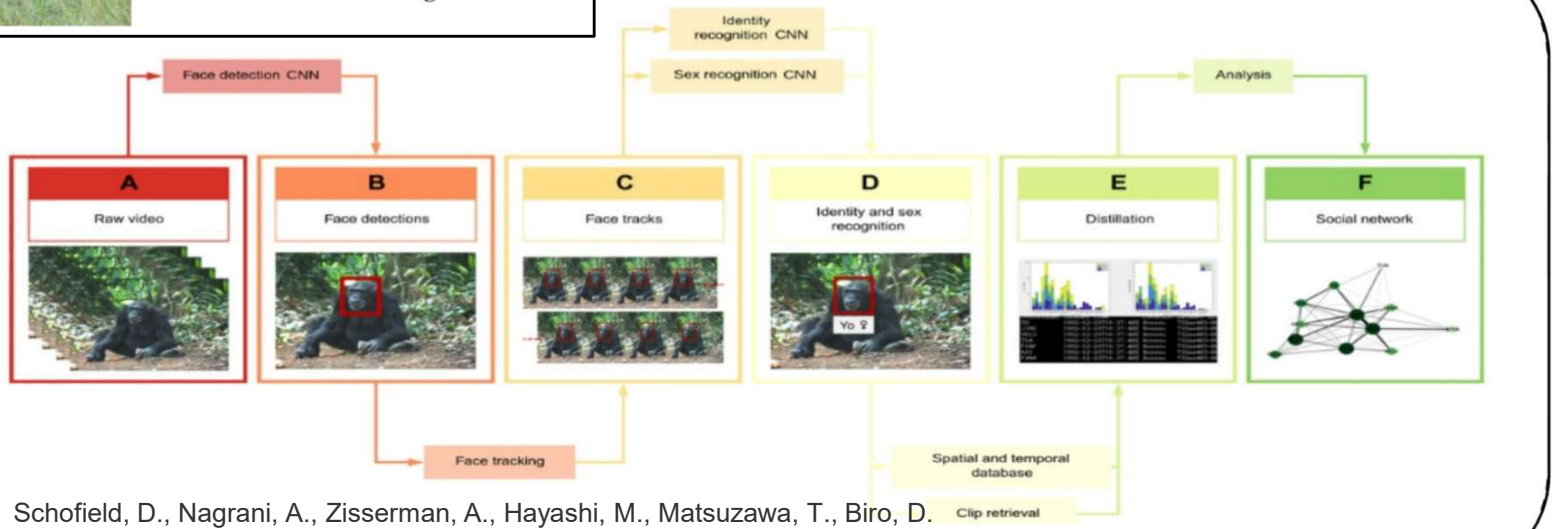
O Brookes, T Burghardt. **A Dataset and Application for Facial Recognition of Individual Gorillas in Zoo Environments.** *Proc. 25th IEEE/IAPR International Conference on Pattern Recognition (ICPR) Workshop on Visual Observation and Analysis of Vertebrate And Insect Behavior (VAIB)*, 2021. (Workshop Paper), (Arxiv PDF), (GitHub), (Dataset BristolGorillas2020)



Sanakoyeu, A., Khalidov, V., McCarthy, M.S., Vedaldi, A. and Neverova, N., **Transferring dense pose to proximal animal classes**. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition* (pp. 5233-5242). 2020.

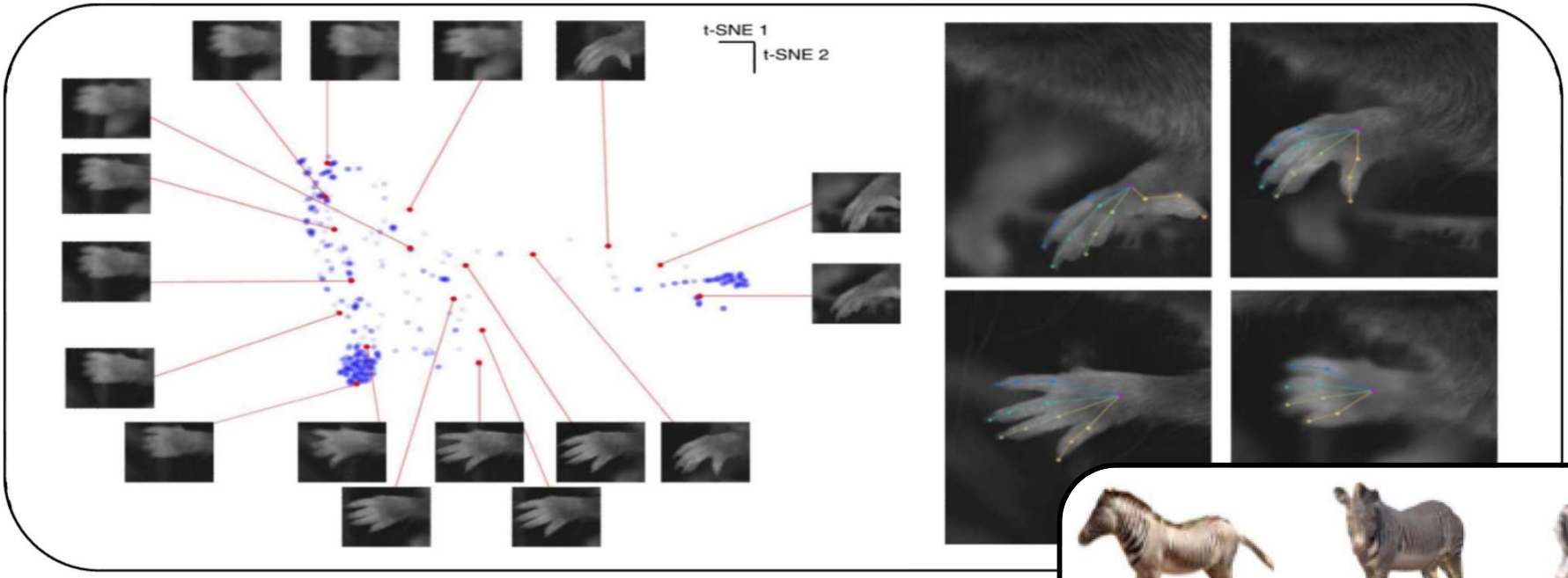


CA Brust, T Burghardt, M Groenenberg, C Kaeding, HS Kuehl, M Manguette, J Denzler. **Towards Automated Visual Monitoring of Individual Gorillas in the Wild.** *Visual Wildlife Monitoring (VWM) Workshop at IEEE International Conference of Computer Vision (ICCVW),* pp. 2820-2830, 2017. (DOI:10.1109/ICCVW.2017.333), (Dataset Gorilla2017), (CVF Version)



Schofield, D., Nagrani, A., Zisserman, A., Hayashi, M., Matsuzawa, T., Biro, D. and Carvalho, S.,. **Chimpanzee face recognition from videos in the wild using deep learning**. Science advances, 5(9), 2019

Body Configuration and Pose Spaces



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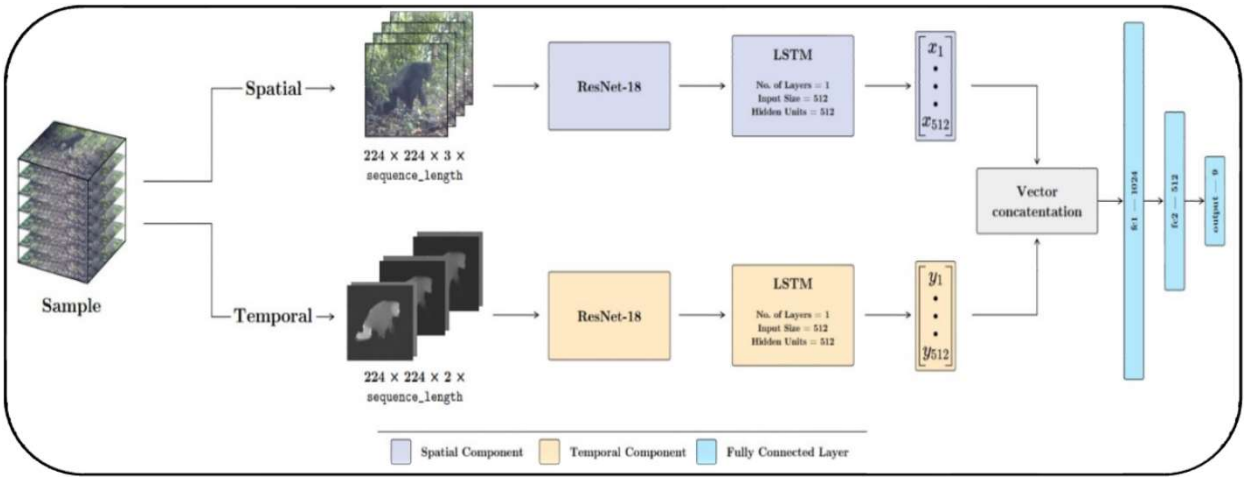
Nature neuroscience, 21(9), pp.1281-1289. 2018.

Zuffi, S., Kanazawa, A., Berger-Wolf, T. and Black, M.J., **Three-D Safari: Learning to Estimate Zebra Pose, Shape, and Texture from Images" In the Wild**". In Proceedings of the IEEE/CVF International Conference on Computer Vision (pp. 5359-5368). 2019.

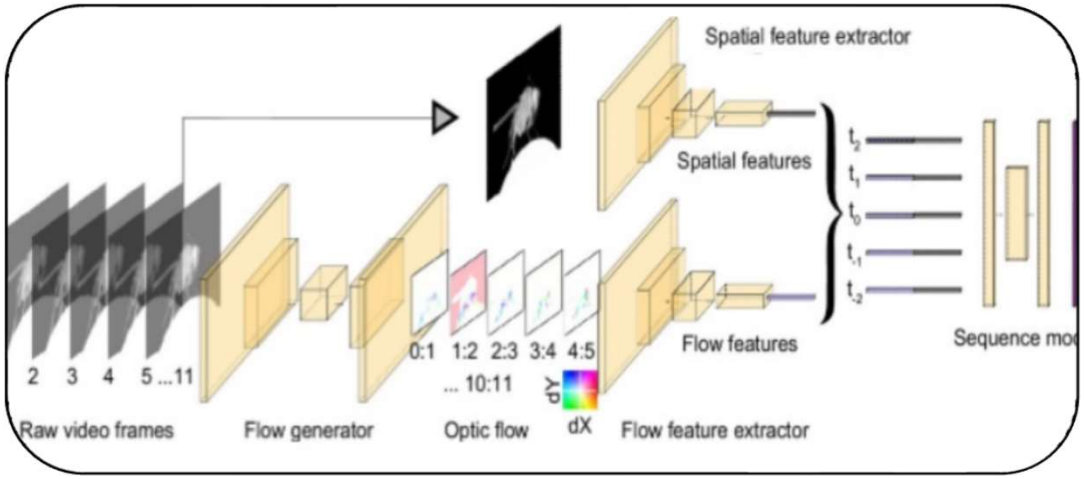
D Tuia, B Kellenberger, S Beery, BR Costelloe, S Zuffi, B Risse, A Mathis, MW Mathis, F van Langevelde, T Burghardt, R Kays, H Klinck, M Wikelski, ID Couzin, G van Horn, MC Crofoot, CV Stewart, T Berger-Wolf. **Perspectives in Machine Learning for Wildlife Conservation.** *Nature Communications*, Vol 13, Issue 1, No 792. February 2022. (DOI:10.1038/s41467-022-27980-y)

‘Closed’ Behaviour Recognition and Construction

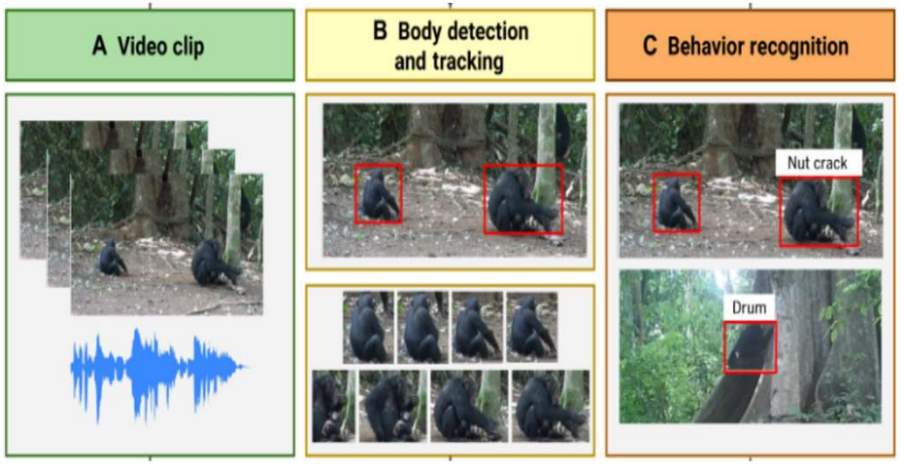


F Sakib, T Burghardt. **Visual Recognition of Great Ape Behaviours in the Wild.** *Proc. 25th IEEE/IAPR International Conference on Pattern Recognition (ICPR) Workshop on Visual Observation and Analysis of Vertebrate And Insect Behavior (VAIB)*, January 2021. (Workshop Paper), (Dataset PanAfrican2019 Video), (Arxiv PDF), (GitHub), (Dataset PanAfrican2020)

(videos © PanAfrican Programme)



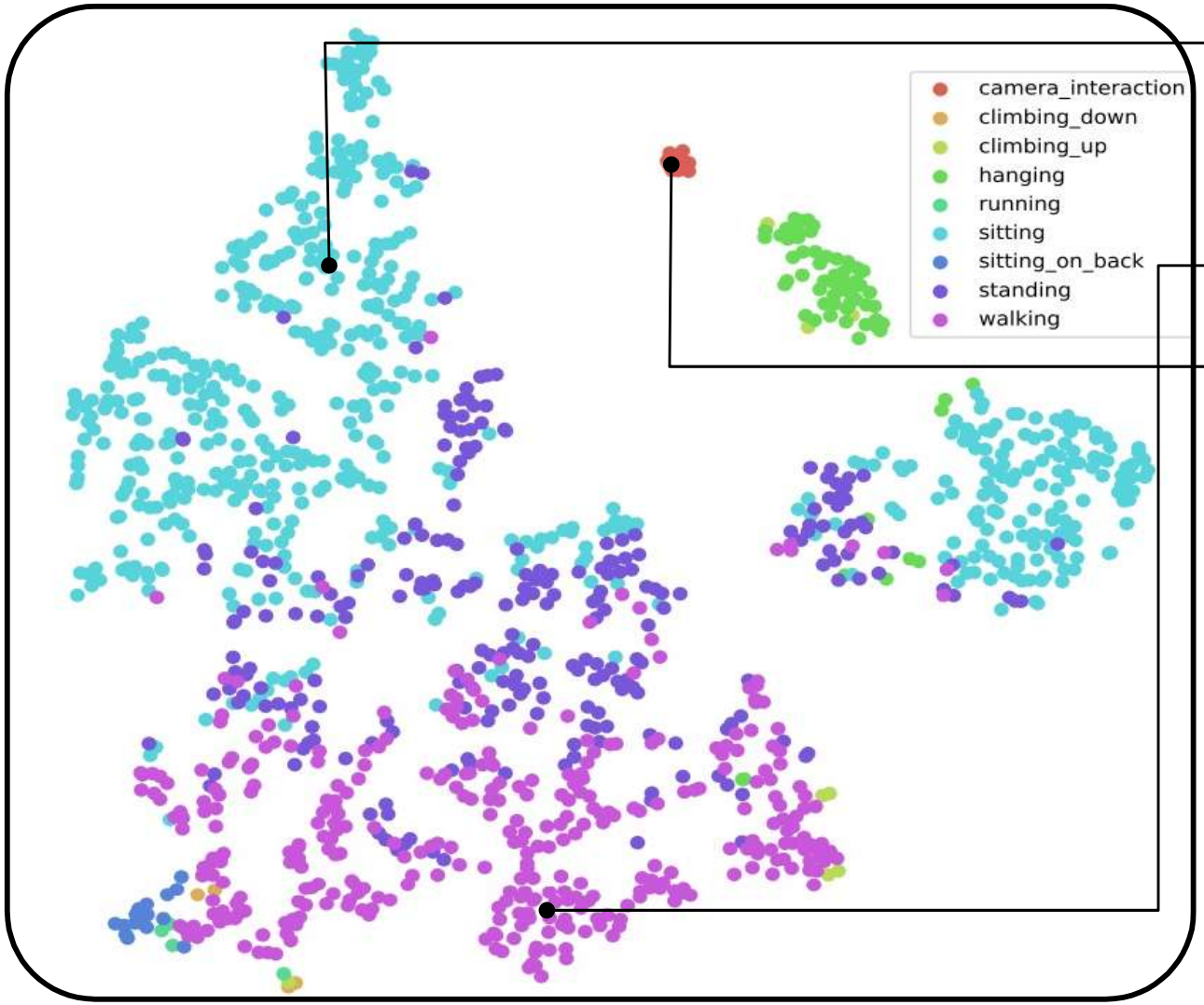
Bohnslav, J.P., Wimalasena, N.K., Clausing, K.J., Dai, Y.Y., Yarmolinsky, D.A., Cruz, T., Kashlan, A.D., Chiappe, M.E., Orefice, L.L., Woolf, C.J. and Harvey, C.D., **DeepEthogram, a machine learning pipeline for supervised behavior classification from raw pixels**. Elife, 10, p.e63377,. 2021.



Bain, M., Nagrani, A., Schofield, D., Berdugo, S., Bessa, J., Owen, J., Hockings, K.J., Matsuzawa, T., Hayashi, M., Biro, D. and Carvalho, S., **Automated audiovisual behavior recognition in wild primates.** *Science advances*, 7(46),2021.

‘Open’ Data-driven Behaviour Spaces in the Wild

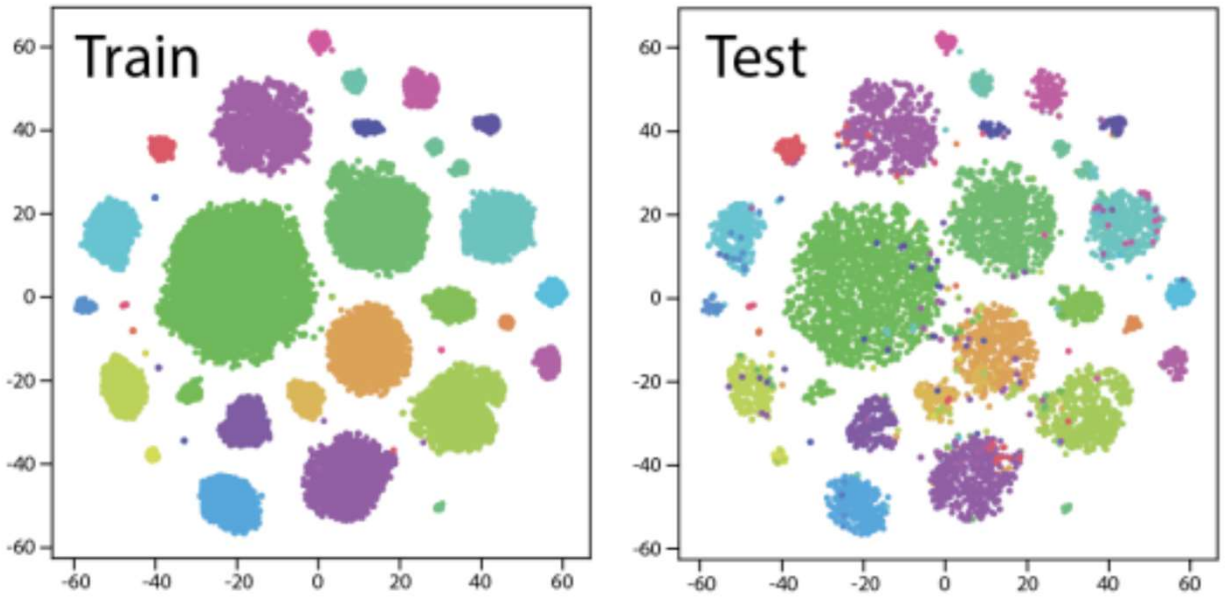
(videos © PanAfrican Programme)

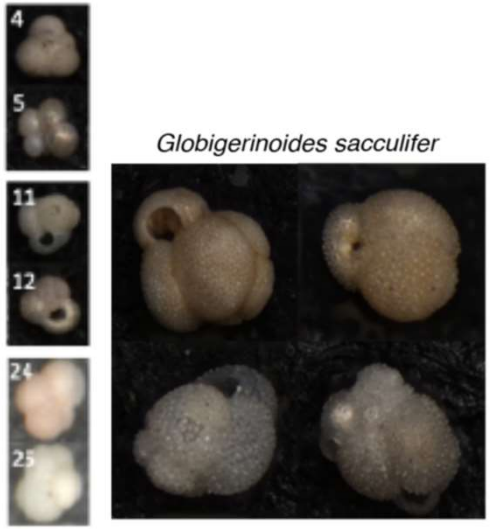


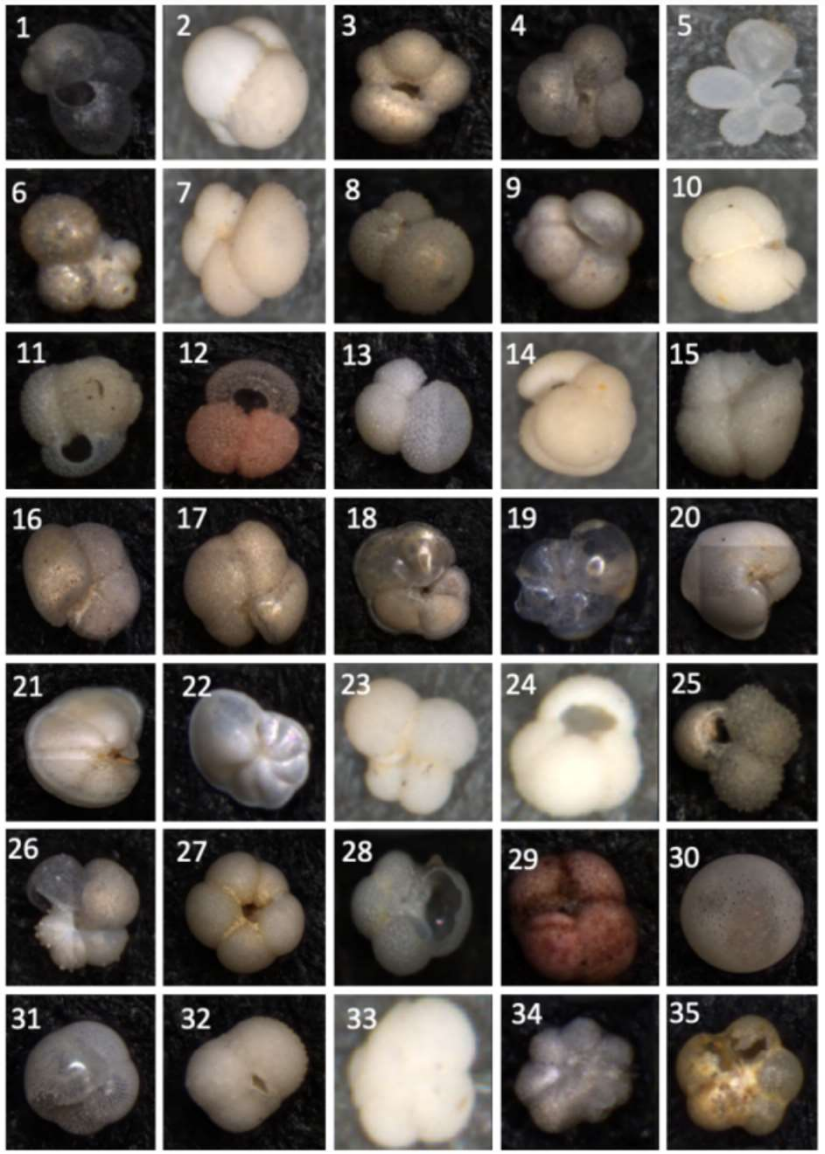
2D t-SNE plot of projection of unseen sample video snippets in learned behaviour space, unpublished ongoing research: O Brookes, H Kuehl, M Mirmehdi, F Sakib, T Burghardt.

F Sakib, T Burghardt. **Visual Recognition of Great Ape Behaviours in the Wild.** *Proc. 25th IEEE/IAPR International Conference on Pattern Recognition (ICPR) Workshop on Visual Observation and Analysis of Vertebrate And Insect Behavior (VAIB)*, January 2021. (Workshop Paper), (Dataset PanAfrican2019 Video), (Arxiv PDF), (GitHub), (Dataset PanAfrican2020)

Example: Data-driven Taxonomic Spaces (Forams)







T Karaderi, T Burghardt, AY Hsiang, J Ramaer, DN Schmidt. **Visual Microfossil Identification via Deep Metric Learning.** In Press. *3rd International Conference on Pattern Recognition and Artificial Intelligence (ICPRAI), Lecture Notes in Computer Science (LNCS),* 2022. (Arxiv PDF)

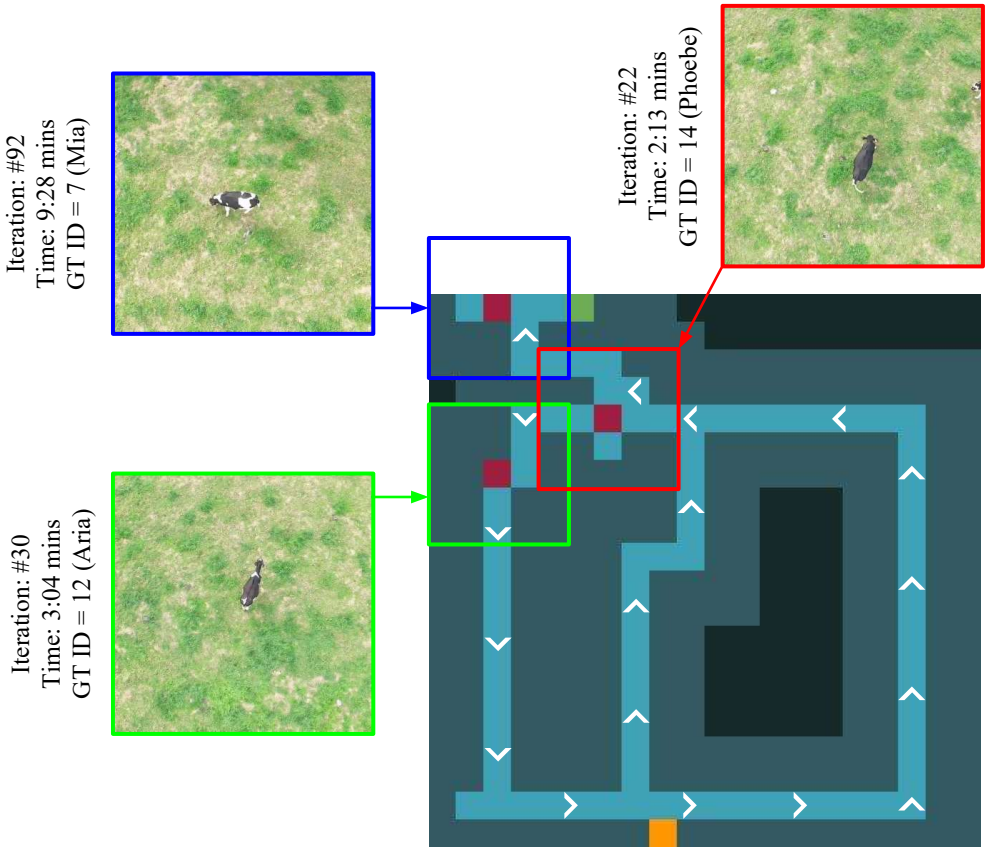
Currently Used ‘Passive or Manual’ Sensing

D Tuia, B Kellenberger, S Beery, BR Costelloe, S Zuffi, B Risse, A Mathis, MW Mathis, F van Langevelde, T Burghardt, R Kays, H Klinck, M Wikelski, ID Couzin, G van Horn, MC Crofoot, CV Stewart, T Berger-Wolf. **Perspectives in Machine Learning for Wildlife Conservation.** *Nature Communications*, Vol 13, Issue 1, No 792. 2022. (DOI:10.1038/s41467-022-27980-y)

HS Kuehl, T Burghardt. **Animal Biometrics: Quantifying and Detecting Phenotypic Appearance**. *Trends in Ecology and Evolution*, Vol 28, No 7, pp. 432-441, 2013. (DOI:10.1016/j.tree.2013.02.013)

Robotic Search + Species Detection + Individual ID

Example Flight Path



Experiment ID = 16
Total flight time: 10:16 mins
Total iterations: 98
Environment coverage: 85.8%

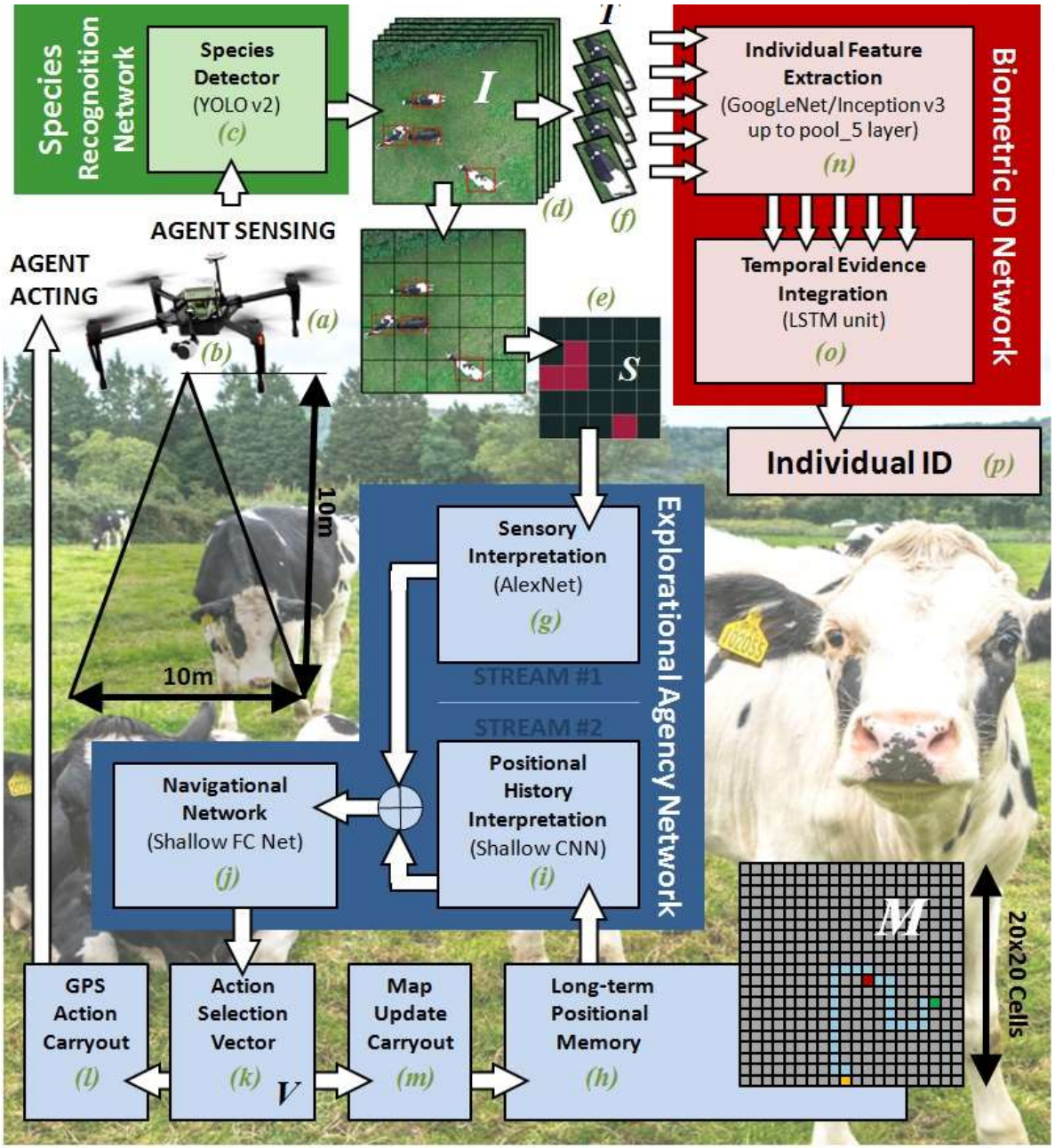
W Andrew, C Greatwood, T Burghardt. **Aerial Animal Biometrics: Individual Friesian Cattle Recovery and Visual Identification via an Autonomous UAV with Onboard Deep Inference.** *32nd IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, pp. 237-243, November 2019. (DOI:10.1109/IROS40897.2019.8968555), (Arxiv PDF), (CVF Extended Abstract at WACVW2020), (Video)

Physical UAV Setup

W Andrew, C Greatwood, T Burghardt. **Deep Learning for Exploration and Recovery of Uncharted and Dynamic Targets from UAV-like Vision.** *31st IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, pp. 1124-1131, October 2018. (DOI:10.1109/IROS.2018.8593751), (IEEE Version), (Dataset GTRF2018), (Video)

W Andrew, C Greatwood, T Burghardt. **Visual Localisation and Individual Identification of Holstein Friesian Cattle via Deep Learning.** *Visual Wildlife Monitoring (VWM) Workshop at IEEE International Conference of Computer Vision (ICCVW)*, pp. 2850-2859, October 2017. (DOI:10.1109/ICCVW.2017.336), (Dataset FriesianCattle2017), (Dataset AerialCattle2017), (CVF Version)

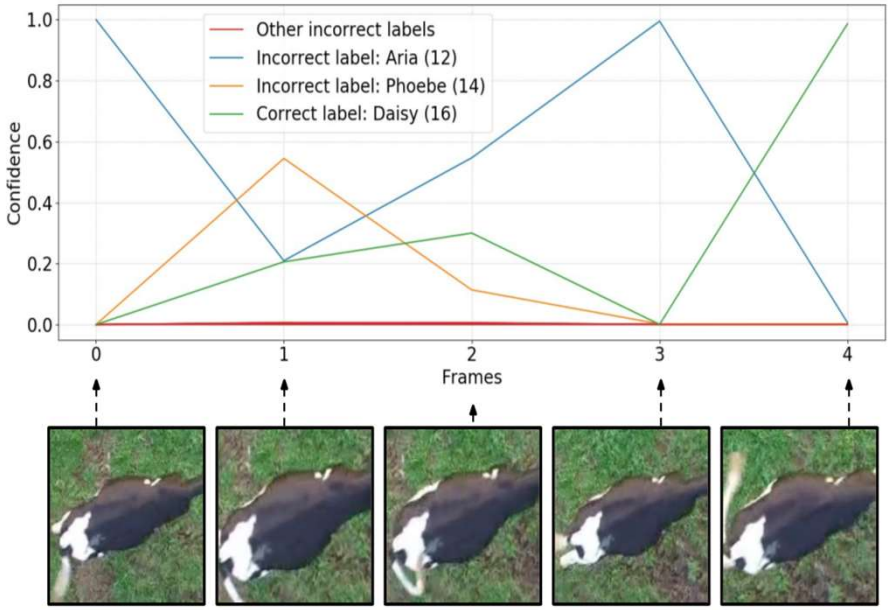
Robotic Search + Species Detection + Individual ID



Online Autonomous Multi-Frame

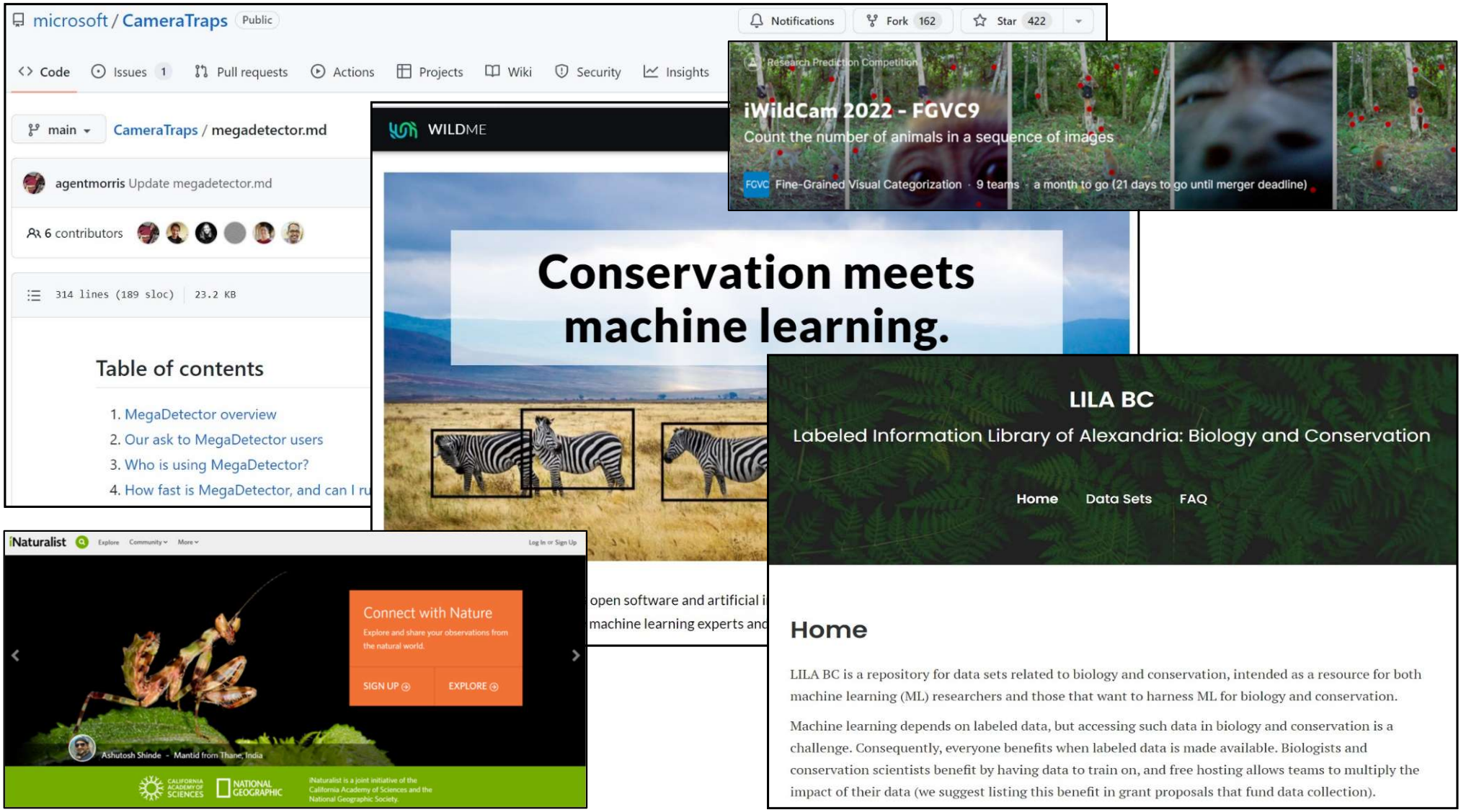
# Samples	LRCN Identification Accuracy (%)	Single Frame Identification Accuracy (%)
18	**100**	94.4

LRCN SoftMax class likelihoods vs. frames



W Andrew, C Greatwood, T Burghardt. **Aerial Animal Biometrics: Individual Friesian Cattle Recovery and Visual Identification via an Autonomous UAV with Onboard Deep Inference.** *32nd IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, pp. 237-243, November 2019. (DOI:10.1109/IROS40897.2019.8968555), (Arxiv PDF), (CVF Extended Abstract at WACVW2020), (Video Summary)

International Datasets, Components, Platforms at Scale



See also: D Tuia, B Kellenberger, S Beery, BR Costelloe, S Zuffi, B Risse, A Mathis, MW Mathis, F van Langevelde, T Burghardt, R Kays, H Klinck, M Wikelski, ID Couzin, G van Horn, MC Crofoot, CV Stewart, T Berger-Wolf. **Perspectives in Machine Learning for Wildlife Conservation.** *Nature Communications*, Vol 13, Issue 1, No 792. February 2022. (DOI:10.1038/s41467-022-27980-y)

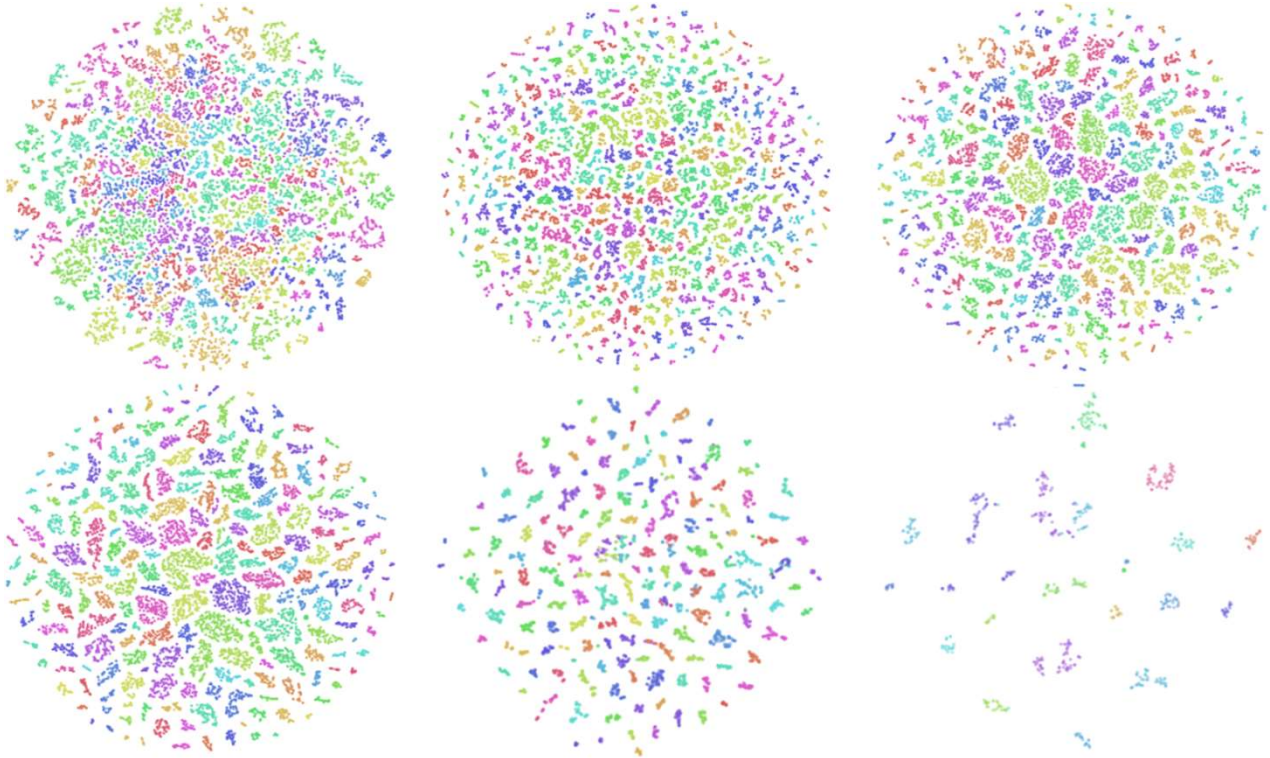
Our Other Recent Animal Biometrics Research Directions I

Self-Supervision and Annotation Reduction

J Gao, T Burghardt, NW Campbell. **Label a Herd in Minutes: Individual Holstein-Friesian Cattle Identification.** In Press. *21st International Conference on Image Analysis and Processing Workshop (ICIAPW) on Learning in Precision Livestock Farming (LPLF), Lecture Notes in Computer Science (LNCS),* May 2022. (Arxiv PDF), (Dataset Cows2021)

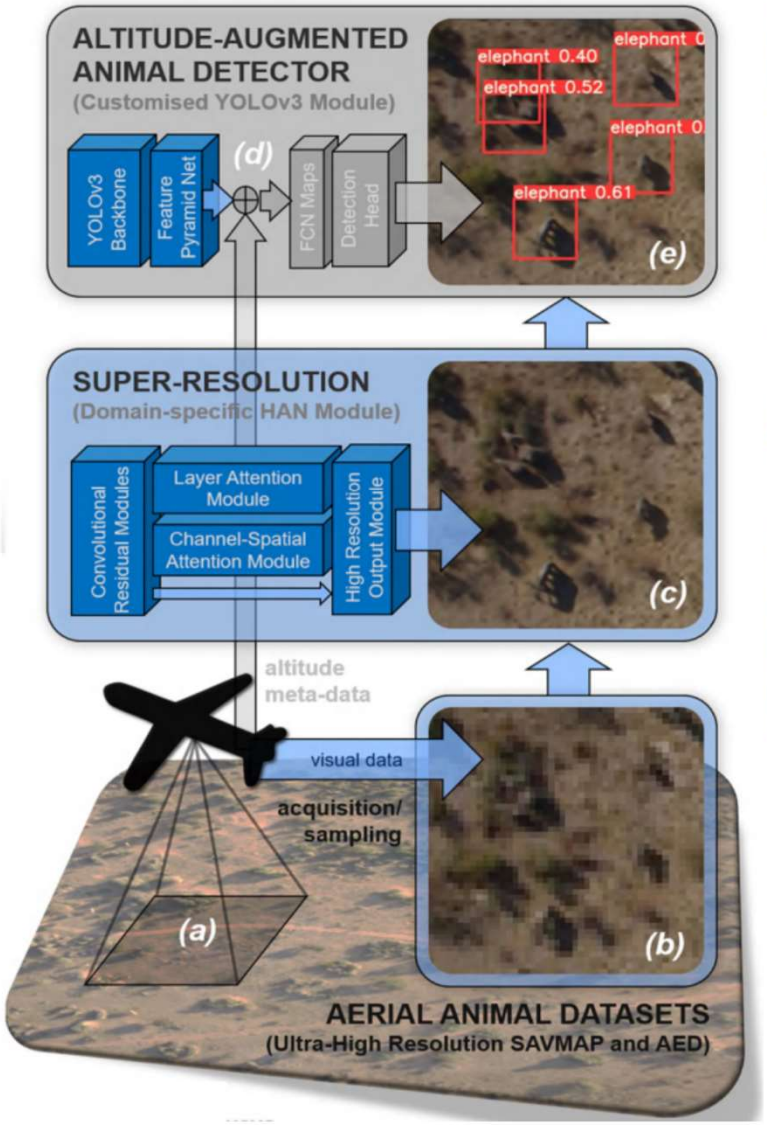
J Gao, T Burghardt, W Andrew, AW Dowsey, NW Campbell. **Towards Self-Supervision for Video Identification of Individual Holstein-Friesian Cattle: The Cows2021 Dataset.** *34th IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshop on Computer Vision for Animal Behavior Tracking and Modeling (CV4Animals)*, June 2021. (Arxiv PDF), (GitHub), (Dataset Cows2021)

W Andrew, J Gao, S Mullan, N Campbell, AW Dowsey, T Burghardt. **Visual Identification of Individual Holstein-Friesian Cattle via Deep Metric Learning.** *Computers and Electronics in Agriculture*, Vol 185, June 2021. (DOI:10.1016/j.compag.2021.106133), (Arxiv PDF), (GitHub), (Dataset OpenCows2020)



Our Other Recent Animal Biometrics Research Directions II

Super-Resolution for Detection, CT Animal Analysis



M Xue, T Greenslade, M Mirmehdi, T Burghardt. **Small or Far Away? Exploiting Deep Super-Resolution and Altitude Data for Aerial Animal Surveillance.** *Real-World Surveillance: Applications and Challenges Workshop (RWS) at IEEE Winter Conference on Applications of Computer Vision (WACVW)*, pp. 509-519, January 2022. (CVF Version), (Arxiv PDF), (GitHub)

A Rutterford, L Bertini, EJ Hendy, KG Johnson, R Summerfield, T Burghardt. **Towards the Analysis of Coral Skeletal Density-banding using Deep Learning.** *Springer Nature Applied Sciences*, Vol 4, Issue 2, No 38, January 2022. (DOI:10.1007/s42452-021-04912-x), (Supplement)