10.1117/2.1201212.004636

Identifying endangered species from footprints

Zoe Jewell and Sky Alibhai

A technique that analyzes images of animal footprints provides reliable data on endangered wildlife populations and individuals.

To protect endangered species and understand extinction threats, we need effective monitoring techniques. Biologists have documented around one million species, which represent only 1–10% of all those on earth. Less quantified, however, is how human activity elevates local extinction rates, particularly in vulnerable endemic populations.[1] Furthermore, existing methods for monitoring are variable in effectiveness. One approach is to attach telemetry devices to wildlife,[2] but this can have negative effects on the animal, inducing pathological stress,[3] altered behavior,[4] and reduced female fertility.[5] Such invasive approaches are also costly and rarely involve local communities, whose commitment to the conservation project is essential. We need low-cost, non-invasive, and community-friendly monitoring techniques for sustainable and effective conservation, without negative impacts.

Technology is providing new methods for wildlife observation. The use of remote cameras,[6] tracking patterns in vocalization[7] and coat,[8] and analyzing DNA from feces and hair[9] are all valuable in identifying individuals but can have a limited range of application, low accuracy, and high cost. Footprints, by contrast, are ubiquitous on suitable substrates, cheap to collect, and can provide good biometric markers. Some scientists have identified small numbers of captive individuals from footprints, but have had difficulty scaling up the work for larger numbers, in classifying at different levels, and in applying the technique to wild populations.[10–12]

We worked for many years with expert trackers in Africa and observed their accuracy in identifying individuals from footprints along trails in the bush. To translate their techniques for modern technology we needed a robust analytical tool, capable of effective discrimination on the basis of species, individual, sex, and age-class. There are several levels of complexity in footprint identification. Every species has a unique footprint anatomy, and every individual of a species a unique footprint.

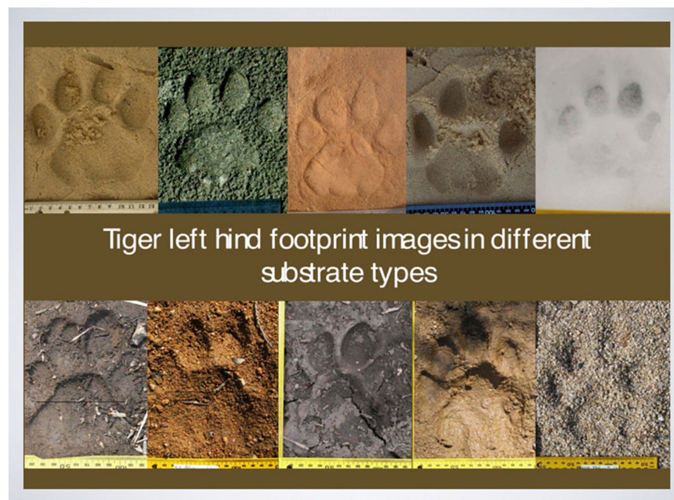

Figure 1. *Left hind tiger footprints in different substrates, which are ubiquitous and provide good biometric markers. (Photo courtesy of WildTrack.)*

In addition, every footprint produced by an individual is also unique because of the substrate (see Figure 1), gait, weather conditions, and terrain. A model incorporating these variables must minimize the considerable variation in footprints produced by an individual, while maximizing the variation that occurs between one individual and another.

Using our footprint identification technique (FIT), we take a series of digital images along several different trails, according to a standardized photo protocol. We place a metric ruler on the horizontal and left axes of the footprint, and an information slip recording global positioning system, date, photographer, and track number near the ruler (see Figure 2). We import the image into JMP Software (SAS Institute) and manually place landmarks at specific anatomical points on the image. A JMP script takes more than 120 measurements of areas, lengths, and angles from the footprint.[13] We extract the variables that provide best classification using stepwise selection, and compare the trails using a

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customized model, based on a cross-validated pairwise discriminant analysis, with Ward's clustering technique. This presents individual identification through a cluster dendrogram (or tree diagram). Discriminant analysis alone provides sex, age-class, and species,[13] and our technique gives accuracy rates of greater than 90% in determining these characteristics.

FIT identifies each species initially by an algorithm extracted from a training set drawn from captive animals. We then apply this algorithm to a free-ranging population. In a short video available online,[14] we show the process of collecting footprints from captive and free-ranging Amur tigers (see Figure 3). Using large, thoroughly validated training sets, and by testing with subsets of known free-ranging individual animals, we can successfully demonstrate the technique's use for identifying wild as well as captive animals.

We have adapted FIT for several species, including black rhino, white rhino, Amur tiger, Bengal tiger, polar bear, cougar, cheetah, Baird's tapir, lowland tapir, and several small mammals at species level. We are writing the first general release of FIT software in JMP (FIT v.1) to incorporate variable extraction, data analytics, and mapping options. This will provide a complete tool for biologists to monitor endangered species.

Figure 2. *Amur tiger left hind footprint in snow. Photographs of footprints are imported into software that analyzes anatomical markers. (Photo courtesy of Jiayin Gu.)*

Figure 3. *Amur tiger, tracked in northeast China. (Photo courtesy of WWF China.)*

The expert positioning of landmark points on footprints is the most accurate method, to date, for classifying individuals and is still the gold standard in similar fields, such as medical imaging. However, our quest continues for an automated feature extraction that is accurate, cost-effective, and fieldworthy. Structured lighting,[15] polynomial texture mapping,[16] and invariant moment approaches[17] could potentially provide accurate automated feature extraction, but have yet to match the accuracy of manual segmentation. With North Carolina State University and Tom Malzbender,[16] we are exploring a new approach, using a Kinect motion sensor camera, possibly in conjunction with structured lighting techniques, to generate a depth map. Our aim is to produce a fast, cheap, reliable, and user-friendly tool for wildlife conservationists to monitor endangered species using footprints. Meanwhile, we remain humbled by the extraordinary tracking skills that evolved with our ancestors thousands of years ago.

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References

1. S. L. Pimm, *Extinction*, in W. J. Sutherland ed., **Conservation Science and Action**, pp. 20–38, Blackwell, Oxford, 2009. doi:10.1002/9781444313499
2. S. K. Alibhai and Z. C. Jewell, *Hot under the collar: the failure of radio-collars on black rhino (Diceros bicornis)*, **Oryx 35**, pp. 284–288, 2001.
3. Z. C. Jewell and S. K. Alibhai, *Ethics and the immobilization of animals*, in M. Bekoff ed., **The Encyclopedia of Animal Rights and Welfare**, 2nd ed., pp. 259–265, Greenwood Press, Oxford, England, 2010.
4. Y. Ropert-Coudert, C.-A. Bost, Y. Handrich, R. M. Bevan, P. J. Butler, A. J. Woakes, and Y. Le Maho, *Impact of externally attached loggers on the diving behaviour of the king penguin*, **Phys. Biochem. Zool. 73**, pp. 438–445, 2000.
5. S. K. Alibhai, Z. C. Jewell, and S. S. Towindo, *The effects of immobilisation on fertility in female black rhino (Diceros bicornis)*, **J. Zool. 253**, pp. 333–345, 2001.
6. K. U. Karanth, J. D. Nichols, N. S. Kumar, and J. E. Hines, *Assessing tiger population dynamics using photographic capture-recapture sampling*, **Ecology 87**, pp. 2925–2937, 2006.
7. A. M. R. Terry, T. M. Peake, and P. K. McGregor, *The role of vocal individuality in conservation*, **Frontiers Zool. 2**, p. 10, 2005.
8. L. Hiby, P. Lovell, N. Patil, N. S. Kumar, A. M. Gopalaswamy, and K. U. Karanth, *A tiger cannot change its stripes: using a three-dimensional model to match images of living tigers and tiger skins*, **Biol. Lett. 5**, pp. 383–386, 2009. doi:10.1098/rsbl.2009.0028
9. P. Taberlet and G. Luikart, *Non-invasive genetic sampling and individual identification*, **Biol. J. Linnean Soc. 68**, pp. 41–55, 1999. doi:10.1111/j.1095-8312.1999.tb01157.x
10. P. Riordan, *Unsupervised recognition of individual tigers and snow leopards from their footprints*, **Animal Conserv. 1**, pp. 253–262, 1998.
11. S. Sharma, Y. Jhala, and V. B. Sawarkar, *Identification of individual tigers (Panthera tigris) from their pugmarks*, **J. Zool. 267**, pp. 9–18, 2005.
12. M. M. Grigione, P. Burman, V. C. Bleich, and B. M. Pierce, *Identifying individual mountain lions Felis concolor by their tracks: refinement of an innovative technique*, **Biol. Conserv. 88**, pp. 25–32, 1999.
13. S. K. Alibhai, Z. C. Jewell, and P. R. Law, *Identifying white rhino (Ceratotherium simum) by a footprint identification technique, at the individual and species levels*, **Endangered Species Res. 4**, pp. 219–225, 2008. http://www.int-res.com/articles/esr2008/4/n004p205.pdf
14. http://spie.org/documents/newsroom/videos/4636/TigersNewsroom.mov Video detailing the field processes for developing an FIT algorithm for Amur tiger monitoring in China. *Credit: Jiayin Gu, North-East Forestry University, Harbin, and WildTrack.*
15. D. Fofi, T. Sliwa, and Y. Voisin, *A comparative survey on invisible structured light*, **Proc. SPIE 5303**, 2004. doi:10.1117/12.525369
16. M. Mudge, T. Malzbender, C. Schroer, and M. Lum, *New reflection transformation imaging methods for rock art and multiple-viewpoint display*, **7th Int'l Symp. Virtual Reality Archaeol. Cultural Heritage VAST**, 2006.
17. F. B. Neal and J. C. Russ, **Measuring Shape**, CRC Press, 2012.