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To cite this article: C Lavers et al 2005 J. Phys.: Conf. Ser. 15 207

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Application of remote thermal imaging and night vision technology to improve endangered wildlife resource management with minimal animal distress and hazard to humans

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Abstract. Advanced electromagnetic sensor systems more commonly associated with the hightech military battlefield may be applied to remote surveillance of wildlife. The first comprehensive study of a wide global variety of Near Infra Red (NIR) and thermal wildlife portraits are presented with this technology: for mammals, birds and other animals. The paper illustrates the safety aspects afforded to zoo staff and personnel in the wild during the day and night from potentially lethal and aggressive animals, and those difficult to approach normally. Such remote sensing systems are non-invasive and provide minimal disruption and distress to animals both in captivity and in the wild. We present some of the veterinarian advantages of such all weather day and night systems to identify sickness and injuries at an early diagnostic stage, as well as age related effects and mammalian cancer. Animals have very different textured surfaces, reflective and emissive properties in the NIR and thermal bands than when compared with the visible spectrum. Some surface features may offer biomimetic materials design advantages.

1. Introduction

Thermography has been used since the ancient Egyptians to monitor skin temperature change by moving fingers across a body surface, but until recently only the military possessed the ability to see in complete darkness or through the heavy dust and smoke of battlefield conditions [1]. With the end of the Cold War, these technologies found their way into the civil sector. Affordable thermal imaging and night vision technology brings vision enhancement advantages to a broad spectrum of commercial applications. Infra Red (IR) technology is now a valuable tool in diverse fields such as: medical research, archaeology, Search and Rescue and law enforcement. Recent advances have improved image quality, reduced cost and weight, and built-in processing ability. Most thermal imagers use **staring** imaging arrays sensitive to 3-5 microns or 8-12 microns radiation. Imagers provide data on relative temperature distribution over a scene. *Radiometric* systems give calibrated temperature measurement at points or across the entire display.

Recent work, in partnership with one of Europe's foremost zoological Parks, Paignton Zoo, in the South West of England, using a heat sensitive camera and NIR camera demonstrates they can remotely

evaluate a broad range of endangered and vulnerable wildlife species in captivity without stress, applicable to environmental management and evaluation in the wild. The camera provides additional information to the veterinarian.

We extended previous work of comparative River Dart estuary visible, NIR and heat photography [2-3], to examine animals that can be hard to view, especially if there is significant ground cover or images are required nocturnally. IR cameras detect small surface radiated intensity differences of endangered wild animals protected in captivity. By displaying image intensity differences with false colour representation (one simple representation has blue as cold and white as hot) we view animal behaviour and numbers where it would be difficult otherwise to do so. Heat images have now become widely accepted in the equine field for diagnosis of horse conditions [4]. Thermography can highlight irritated or inflamed tissue easily but is not a catch-all technique. Heat cameras cannot see through glass; water absorbs heat so we cannot directly view *in-vivo* ocean species. However, removal of marine species from water for a short time is possible and may be supplemented by NIR species images in shallow water or behind glass. Passive thermal imaging is less suited for reptiles with little internal heat and is not always good for small mammals heavily coated with fur. In spite of these limitations thermal imaging is demonstrated over a broad range of species. Thermography offers safety advantages to zoo staff and researchers in the wild and will aid correct diagnosis of animal conditions.

All objects above Absolute Zero emit IR, and as the radiated energy wavelength distribution is proportional to T^4 , the Absolute temperature and ε the emissivity, small temperature changes give rise to large IR emission changes. Objects with small temperature difference are easily detected, especially if object and background emissivity are different. Some biological tissues resemble a 'black body' in IR emission; human skin has an emissivity of 0.98 which means only 2% of heat is reflected at the skin/air boundary. A high emissivity means an object absorbs and radiates most of the incident energy. Humans and many animal bodies are efficient heat radiators and it is possible to detect heat emission from the skin, creating a heat distribution over the body that can be monitored remotely.

As peak emission wavelength, λ_{peak} , is related to T: $\lambda_{peak} = 2900 / T$ in microns, most animals near ambient have peak emission near 10 microns in the FIR. Targets may be viewed in different wave bands, ideal for analysis & identification. As IR cannot be seen by eye, it is implicit that received IR is converted to visible light by means of a display unit. 'False' colours may be used to represent different wave bands or intensity levels. Colours are chosen to increase Contrast and reveal detail which might be missed. Image Intensifiers (II) amplify light and NIR up to 100,000 times but don't work in total darkness; they requires no artificial light source, are passive and with correct filters can be used for day-time observation. Image Intensifiers are used in night observation devices, driving sights & flying goggles and can be fitted to low light level CCTV camera systems, but cannot 'see' through fog, mist or smoke.

2. Experimental Arrangement

2.1 Preliminary test work

Thermal, Visible and NIR photographic data was collected from the Dartmouth Castle site over a 9month period. A key aim was to test the validity of using NIR and False Colour Representation (FCR) to aid analysis. To ensure accurate image fusion and analysis cameras were registered spatially as closely as possible and tripod mounted in the same location each week. The Castle at the River Dart's mouth faces East towards the village of Kingswear providing remote observation of: buildings, a road, fields, woods and the river. Cameras were located opposite the Castle, under a public viewing platform.

We trialled one method to consider enhancing image recognition for humans with FCR of individual waveband images and composite fused images for an environmental scene appropriate to wildlife applications. We took an empirical observer-based approach towards image fusion, to enhance observer information with results of a questionnaire submitted to 47 students to look at key trends for analysis.

Environmental scene analysis by a human operator benefits from combined or fused image representation of a scene taken in different spectral bands. Military sensing has for some time investigated fusion of thermal and NIR images [5]. Different bands offer superior object contrast under varied environmental conditions, e.g. target thermal heat is visible at night when a visible image is no longer possible. However Far Infra Red thermal bands may be less detailed due to low contrast notably near dawn and dusk or after heavy rain. Comparison of visible images with NIR photography revealed dramatic increases in springtime chlorophyll plant reflections, 'highlighting' spring growth. It was anticipated that variations in certain species, especially those with summer and autumn camouflage variations for survival would exhibit similar features.

2.2 Experimental Apparatus

Visible and NIR images were acquired with a Yashica FX-3 Single Lens Reflex (SLR) camera with a 50mm lens and appropriate filters such as a HOYA 52mm IR (R7) filter for NIR images, and a visible Hoya Green filter. Ilford SFX 200 Black and White film was used. This equipment was used for wildlife studies and supplemented in April 2005 with a SONY CCD-TR425E NIR sensitive Video camera and filters, including R7. A Raytheon PalmIR Pro Thermal Imaging Camera stored images on a Sandia Flash Memory card. This camera contains a Focal Plane Array (FPA), an array of 320×256 pixels, operating in the 8-14 micron band, equipped with a 25mm f/1 Germanium lens.

2.3 Initial Image Analysis

Triad images were scaled so they covered the same sub-region (spatially co-registering selected points on images of different resolution to create the same number of pixels covering the sub-image region) with MatLab[™] to generate scaled image outputs. Visible and NIR give textural detail but can be different. Thermal heat tends to be 'fuzzy' as heat spots with little detail, due to the large range of 'warm' buildings. One aim was to fuse detailed Visible and NIR templates with hot spots, giving enough of each of the triad to 'see' all the information to help thermal identification.

A typical summed image is given here in figure 1a for Matrix weightings 1/3%:1/3%:1/3% on the Visible, NIR and Thermal bands recorded on October 23rd 2002 at 1545 hours BST. Different weighting conditions generate different fused images. Further output images were generated utilising FCR for just NIR from a Black and White intensity map, figure 1b.







Figure 1b NIR-False Colour Red High reflectance Blue Low reflectance

Coloured image products allow areas to be highlighted within the overall image template. Image outputs were tested empirically with human observers. UK and overseas degree students aged 18-38 were tasked to locate specific features in chosen images and decide which best displayed selected features for different weighted output conditions. From most student results [2] NIR image FCR was better than its B&W counterpart. From this test work we expected thermal images and NIR wildlife

images, especially in false colour representation, to enhance the ability to observe specific animal features of interest.

3. Zoo Thermal work

3.1 General thermal health

Heat distribution of a healthy rhino in figure 2 shows the hot back and spinal region (like a hot pipe of warm blood near the animal surface), warm feet and relatively cool sides (organs some distance from the surface which is covered with strong muscle tissue).



Viewing Paignton's African elephant with a heat imager revealed the right foot radiating more heat than normal. The IR camera easily detects hot spots indicating increased blood within and around irritated tissue. The elephant is seen in a highlighted mode showing a smaller irritation on its front right shoulder (figure 3a). These features are likely to be interlinked with an elephant favouring one leg over the other; a 4 ton elephant will exert a considerable pressure on both feet and shoulder joint regions! Further keeper examination and corrective care ensures that significant problems are avoided. *Pachyderm* in the UK's damp and wet conditions are known to develop problems in and around the feet and nails. Several months later (April 2005) we observed damage to the Asian elephant by the African's tusk puncturing skin in several places, seen in figure 3b with a heat distribution associated with a bruised area over the right eye.

An ostrich thermal image (figure 4) reveals asymmetries in an individual animal's heat distribution in keeping with left/right hand comparisons and against a second ostrich. Under normal conditions left-right, front-back human skin in symmetric areas are assumed to be similar. Asymmetry in skin temperature of symmetric body areas is used as an indicator of pathology in many diseases [6]. Over a month interval this asymmetry diminished. It is worth considering that ostrich leg examination is best at a distance as they are capable of disembowelling a grown man with their powerful clawed feet!



Figure 4

3.2 Camouflage and Contrast

Some species exhibit striking thermal contrast with FCR after summer moult such as Bactrian camel and Buffalo (figure 5a). Surprisingly visible (figure 5b) and NIR (figure 5c) buffalo images exhibit not only large contrast changes across moulting fur regions but images also have **reverse** contrast to the FIR. Work is underway to evaluate contrast relationships between Visible/NIR and thermal images of the same animal, although there is <u>no intention</u> currently to image fuse wavebands as animals move too fast between multiple image capture. Nonetheless NIR FCR will be explored.



Visible and NIR Zebra images (figure 6a), familiar to WW1 dazzle ship camouflage, appear similar. Pigments responsible for visible absorption also absorb in the NIR although it is known that the iridescence of peacocks feathers and butterflies result from physical structure rather than pigmentation [7]. Zebra patterns are also visible in thermal images, figure 6b. Unlike common military camouflage clothing which exhibits no obvious patterning in the FIR the Zebra retains a residual stripe pattern. Black stripes not only have high emissivity but low visible reflectance; this means black stripes will absorb visible radiation and will both absorb and reradiate in the heat bands efficiently at longer wavelength giving a **negative** of the visual image. A cancer hotspot on the inner rear left leg is also visible.



3.3 Pregnancy

A pregnant miniature water buffalo radiated noticeably more heat from its under belly region. Our new radiometric camera will allow accurate evaluation of surface temperature of pregnant animals and importantly at an early stage of pregnancy. Heat, remotely sensed, allows evaluation of endangered and vulnerable wildlife species in captivity without stress, and may be applied to evaluation in the

wild. Animals exhibit no concern while passive thermal imaging is taking place, either at close or long range, a benefit to both animal subjects and keepers alike!

4. Conclusion

We have demonstrated some key benefits of using thermal and NIR imagery in safe wildlife observation, diagnostics, and camouflage considerations. A future aim will be to acquire complementary images of selected wildlife scene over a long period in at least 3 spectral bands: Visible, NIR, and FIR and to observe any trends. Further image processing will look at boundary extraction using multiple images and the extraction of body features of interest to incorporate features such as threshold detection to minimise noise affects and saturation adjustment [6]. Work is currently underway to evaluate inter and intraband contrast values of the same animal, although there is no intention to image fuse animal wavebands. However, NIR false colour representation will be explored. Further basic work seeks to increase the portfolio of animals and establish a reference baseline for future animal welfare comparisons and behaviour studies.

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