Notes and records

Zebra fingerprints: towards a computer-aided identification system for individual zebra

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Introduction

Information regarding wildlife behavioural patterns provides researchers with clearer understanding of species. Social interactions, breeding habits, feeding and migration trends are key factors influencing decisions in game management and ecological impact assessment. In order to obtain such information researchers must be able to track individual animals over a period of time. One of the commonest methods of identifying individual animals is to tag them with radio, satellite, or GPS transmitters (Mech & Barber, 2002). While these systems are very effective, they are often costly and can be traumatic for tagged animals.

If a species has naturally distinctive individual features, tagging may be avoided altogether. Instead photographs can provide positive identification (Forcada & Aguilar, 2000). One problem with this solution is that analysing the photographs accurately requires training and/or experience. The process is also tedious and time consuming. However, computer-aided matching has provided an accurate and efficient way to analyse photographs (Lebbe & Vignes, 1998). By automating the examination of photographic data, an animal-specific expert is no longer essential to the identification process. Additional benefits may include lower costs, faster matching, scalability, and system portability.

Peterson (1972) has indicated that it is possible to identify individual zebra (*Equus burchelli*, Gray) based on their stripe pattern. Stripe characteristics at various regions of the animal's body (neck, sides, shoulders and legs) are manually compared with an existing file index for identification. Peterson's method is time consuming and may require several photographs of an individual animal at various angles before successful identification is possible. In this study, we investigate developing a computer-aided system for individual zebra identification based only on the lateral side stripe pattern.

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Materials and methods

As zebra stripes have a similar pattern to that of human fingerprints, the model we propose for individual animal identification is based on a combination of image processing (Gonzalez & Woods, 1992) and fingerprint identification technology (Roddy & Stosz, 1999). We chose to develop the system as a plug-in for ImageJ (http://rsb.info.nih.gov/ij/), which is written in Java, as it supports the imaging requirements of this study.

Approximately 20 min of zebra footage was filmed at the Amakhala Game Reserve (about 40 km west of Grahamstown, South Africa) using a Panasonic NV-RZ10 video camera (Matsushita Electric Industrial Co. Ltd., Osaka, Japan). We used a video camera as this provided us with good zoom functionality and allowed for numerous still frames to be obtained of animals at the appropriate side-on orientation. Over 600 single frames were then captured using a video capture card and Video4Linux software (http://www.video4linux.net/). A subset of 50 of the best images (zebra side-on) were chosen to represent the data set of images.

The original captured frames were blurry and noisy (Fig. 1a). The degradation in image quality was corrected using de-interlacing (Fig. 1b) and smoothing (Fig. 1c). Binarization (Fig. 1d) was also performed to make stripe patterns as clear as possible for further processing. A polygonal area representing the lateral stripes of a zebra was segmented from the original image, thus defining the region of interest (ROI). The ROI was defined by selecting six points on the image (Fig. 2). These points represent easy-to-identify body regions and provided the largest portion of the stripe pattern. Defining the ROI is the only significant manual step in the identification process. Following the method outlined by Sonka, Hlavac & Boyle (1999), and implementing Jordan's theorem, the binarized

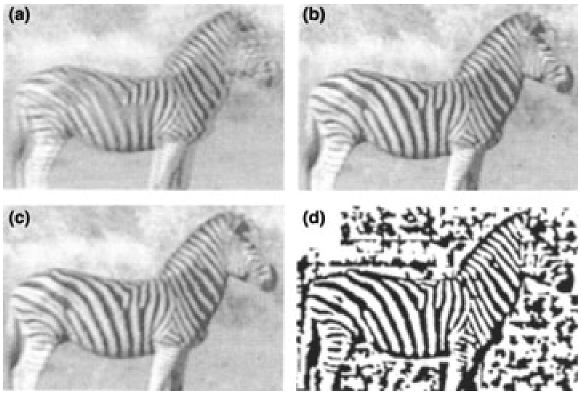

Fig 1 Image preprocessing techniques. (a) Original image showing degradation, (b) image corrected using de-interlacing, (c) image smoothed to reduce noise, (d) image binarized for further processing

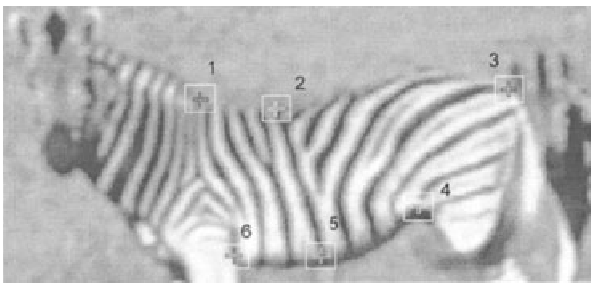

Fig 2 Points used to define the region of interest. (1) Base of neck, (2) middle of back, (3) tail, (4) front of back leg, (5) lowest point of stomach, and (6) back of front leg

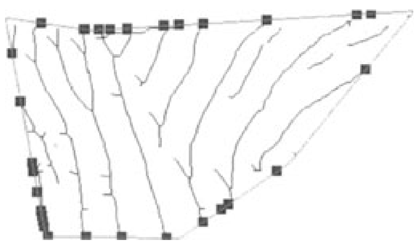

Fig 3 The skeletonized region of interest extracted from an image to be used for zebra identification

ROI stripes were skeletonized to one pixel wide lines (Fig. 3).

In order to determine the accuracy of matching, six randomly chosen zebra images were tested against the data set of known zebra ROI stripes. Three techniques of matching were implemented. First, image overlay matching matches stripe patterns by directly comparing two images. An unknown zebra ROI pattern was matched against stored patterns from the database. The absolute difference of intensities is computed for every pixel. This is added to a cumulative total which is the final score. In order to reduce errors associated with ROI that have slightly different shapes, a warped overlay approach was incorporated to morph stripe pattern to a standard shape. Secondly, vector overlay matching used a vector matrix containing only the most important information (location, direction and curvature) that describes the lateral stripe pattern. Scoring is based on intersections moderated with a radial decay function which is biased towards vertical and horizontal lines, rather than diagonals. Finally, a weighted factor method (which draws on ideas from fingerprint analysis) was used. We identified that the degree of stripe curvature, vertical position of branching points, general stripe direction and the number of stripes at key locations are the most influential descriptors. Once these measurements are found, they are weighted based on their accuracy and importance.

Results and discussion

Simple image overlay showed a large variation between ROI sets, with an average of 68.3 ± 27.7% matching success. This may be attributed to the ROI shape changing markedly from the co-ordinates of the stored data set, thus affecting the final score accordingly. Warped image overlay shows an improved matching success rate of 75.5 ± 17.3%. Matching by vector overlay also exhibited large variation, and had a matching success rate of 76.7 ± 28.6%. Weighted factor matching provided the highest successful matching rate at 79.8 ± 12.5%. In addition, it showed the least amount of variation, thus providing the most consistent accuracy. This may be attributed to it covering the widest range of descriptors, and it is thus the most robust matching technique. We therefore regarded the weighted factor method as having the highest overall performance. However, the accuracy of this method is still poor compared with other matching techniques applied to animal natural markings where it is possible to achieve an accuracy of 96–100% (Hiby & Lovell, 1990; Kelly, 2001).

Fingerprint identification is typically based on minutiae 'maps' (Halici, Jain & Erol, 1999). While there are visual similarities between zebra stripes and human fingerprints, we identify important differences. First, there are a higher number of ridges in a typical print than there are in zebra stripes. Secondly, zebra stripes have more limited patterns, having only branches and occasional islands, whereas fingerprints also contain whorls, loops, waves and trifurcations, and finally, fingerprints have a higher number of interest points than lateral stripe patterns. These differences may therefore contribute to the low accuracy values recorded. However, this preliminary study does indicate that there is sufficient variation in lateral stripe patterns to differentiate individual animals and it should be explored further.

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