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TECHNICAL REPORT

New method of monitoring remote wildlife via the Internet

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A new system of monitoring remote wildlife via the Internet was developed. The system consists of a QuickTime streaming server with a digital PC camera and a recipient computer with monitoring software. Results of field experiments were fine. Wildlife (raccoon dogs and feral cats) inhabiting a forest remote from the observer were monitored and photographed automatically when detected. Data and frame rates were 35–300 kilobits per second and 3–14 frames per second, respectively, depending on the network traffic. This system is applicable wherever a broadband network is available and thus has great potential for ecological research.

Key words: camera trap; CyberHunter Matagi; Internet streaming; Internet technology; remote observation.

INTRODUCTION

Remote-trip cameras or camera traps – cameras in which an animal triggers the shutter – have been used widely in wildlife studies. Time-lapse video cameras have also been used to monitor wildlife (Wemmer *et al.* 1996). These devices are ideal for identifying the species living in a particular area, for monitoring relative and absolute abundance of species, and for studying activity patterns (Kitcher 1961; Karanth 1995; van Schaik & Griffiths 1996; Miura *et al.* 1997; McCullough *et al.* 2000), and have been used to address a variety of ecological and conservation-related questions (Leimgruber *et al.* 1994; Miura *et al.* 1997; Yasuda *et al.* 2000; Otani 2001). However, these methods require relatively expensive equipment, are limited in operation time by film or tape length, and take time to view after retrieval. The greatest disadvantage of these methods is that they are neither computer- nor network-oriented; that is, they are 'offline'.

Internet technology has been developing rapidly and the capacity of the Internet has been increasing. It is now common to broadcast audio and video data via the Internet, known as Internet broadcasting or Internet streaming. Using this technology, one may be able to send live scenes to remote recipients without expensive facilities and high running costs. In this report, we examine an application of Internet streaming technology in ecology, especially to monitor remote wildlife via the Internet. This provides a new method of 'online' and 'live' remote observation. Although Internet streaming can handle both audio and video data, the present study focuses on streaming video data only.

The most basic Internet video streaming–monitoring system consists of a video camera device, a server with streaming software, a recipient computer with monitoring software, and the network between them (Fig. 1). The streaming server compresses and packets video data from the source and sends the packets to the recipient via the network. The recipient computer then reassembles and decompresses the receiving data, and displays in-coming video data on screen. Wildlife is photographed when detected by the monitoring software on real-time.

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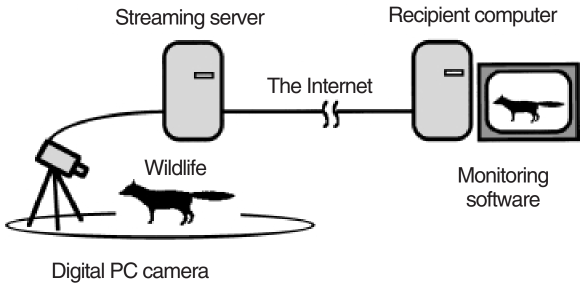

Fig. 1. Scheme of remote observation system via the Internet. The system consists of a streaming server with a digital PC camera and a recipient computer with monitoring software.

In the present report, we first describe the video streaming–monitoring system we developed, including software specializing in monitoring incoming video data. Then we evaluate the system based on the results of a field test. Finally, we discuss the advantages of remote observation systems that use the Internet over other monitoring methods.

METHODS

Video sources, streaming server, and recipient system

Two models of digital PC cameras were used for video sources. One was a Universal Serial Bus (USB) PC camera (PCAM-QUA-iM; NEC Corporation, Tamachi, Tokyo, Japan) and the other was a FireWire (IEEE 1394) PC camera (iBOT; Orange Micro Inc., Anaheim, CA, USA). The former was used intensively in the field experiment, which is described later. Specifications of the USB and FireWire PC cameras are as follows: 1/4″ color charge-coupled device (CCD) image sensor and 24-bit colors for both, 77 000 pixels and 330 000 pixels, respectively, and maximum 20 and 30 fps (frames per second) at 320×240 pixels mode, respectively. Power for the PC cameras was supplied from the computer through the connection cable.

The Internet streaming server we employed consisted of a personal computer (iBook 366 MHz with 64 Mbytes of memory; Apple Computer Inc.) and QuickTime streaming software (CoolStream ver. 1.1; Evological, San Jose, CA, USA; http://www.evological.com/). The iBook was chosen because of its high cost performance, portability, and adaptability for a variety of power supplies, considering intensive field applications in future.

The recipient system consisted of a PowerMac G4 (500 MHz, 256 Mbytes of memory; Apple Computer Inc.). QuickTime Player ver. 4.11 (Apple Computer Inc.) was used as a viewer application of QuickTime streaming.

Video-streaming settings

H.263, a standard video-conferencing compressor/decompressor (CODEC), was selected for video streaming because it has a strong temporal compression component, and works best for movies in which there is little change between frames. The video size (resolution) was 320×240 pixels. Key-frame rate and video quality were set at one key-frame per 24 frames and ‘better’, respectively.

Unicast streaming was employed, which allows video streams to be sent to the Internet provider (IP) address of a single recipient. Unicast streaming is supported by most of the Internet; the only requirement is that intermediate routers and firewalls are configured to allow network traffic on the video port specified in network settings of the streaming software (Evological 2000).

Video-monitoring software

We employed CyberHunter Matagi ver. 1.0 as the video-monitoring software for the recipient computer, which is named after traditional Japanese hunters (developed by ArePass, Fukuyama, Hiroshima, Japan). This software provides an automatic video-monitoring system on a computer by use of an image-motion sensor. Any type of video source, such as a videotape, video camera, or streaming, can be monitored with it. CyberHunter Matagi monitors user-selected monitoring points on a computer screen, up to nine points with the current version. Sensitivity can be adjusted. When any part of an animal’s body appears in any monitoring point, CyberHunter Matagi detects the changes in trichromatic colors at the pixel level and captures the scene as a file. The time of the event is given as the file name in an hour-minute-second format. CyberHunter Matagi is available from Marif Co. (Iwakuni, Yamaguchi, Japan; http://www.marif.co.jp/).

Cost

The cost of the video streaming–monitoring system described was approximately 650 000 Yen, including the both server and recipient computers. This can be reduced greatly when suitable computers on hand are available, of which minimum requirements will be described later. The total cost, excluding computers, was approximately ¥70 000: PC camera ¥20 000, repeater and cables ¥5000, CoolStream US$50, and CyberHunter Matagi ¥30 000.

Field experiment

An experiment of remote wildlife observation using the aforementioned system was carried out for five nights in January and February 2001. The streaming server was set up in the Tama Forest Science Garden (Hachioji, Tokyo, Japan; 35°39′N, 139°17′E) and the recipient computer was set up at the Forestry and Forest Products Research Institute (Tsukuba, Ibaraki, Japan; 36°00′N, 140°08′E). Both computers were set up in a laboratory, and were powered by a 100 V AC electrical current. They were connected to the Ministry of Agriculture, Forestry and Fisheries Research Network (MAFFIN2000) and a fixed IP address was allocated for each. The narrowest capacity of the network between the sender and receiver was 1.0 Megabits per second. The direct distance between them was approximately 85 km.

Sardines and persimmon fruits were used as bait. They were cut into pieces, dressed with mayonnaise, and placed on a feeding plate on the forest floor of a deciduous forest. Animals were prebaited for several days in advance.

The USB PC camera was connected to the streaming server extended with a 6-m long USB cable and a USB repeater, and installed 1 m above the feeding plate. The area around the feeding plate was lit up with a waterproof 500 W light bulb as the experiment was conducted mostly in darkness from 17.00 h to 09.00 h the next day. Sunrise and sunset during the experiment were at 17.05 h and 06.45 h, respectively. Nine monitoring points were scattered surrounding the image of the feeding plate on the screen of the recipient computer.

System verification

A one-night field experiment was videotaped and reinvestigated using the monitoring software on a local computer (PowerMac 7500, 100 MHz, 32 Mbytes memory, MacOS 7.55; Apple Computer Inc.) in order to verify the streaming–monitoring system. Video data was sent from a videotape player to computer through a standard video cable, as the computer had a video input port. Nine monitoring points were scattered surrounding the image of the feeding plate on the screen, as in the field experiment.

RESULTS AND DISCUSSION

Camera trapping

The field experiment was a great success, as 701 photos of raccoon dogs [*Nyctereutes procyonoides* (Gray, 1834), Canidae, Carnivora], and 845 photos of feral cats (*Felis catus* Linnaeus, 1758, Felidae, Carnivora) were obtained over five nights (Fig. 2). At least two and five individuals were distinguished, respectively, according to their appearance. Investigating the digital photos (320 × 240 pixel) of animals, individual identification by fur coloration was easy for feral cats, but not for raccoon dogs.

Visiting times of the two species are shown in Fig. 3, which also shows the time of the first photo in a series of photos taken during an animal's visit. In this example, there were 20 and 43 photos of a raccoon dog and feral cat, respectively. There was a significant difference in the visiting patterns between the two species (Mann–Whitney's *U*-test,

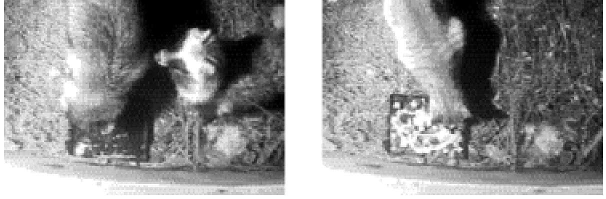

Fig. 2. Photographs of wildlife taken using the monitoring software CyberHunter Matagi. Wildlife inhabiting a remote forest away from the observer was monitored via the Internet and photographed automatically when detected. (a) Raccoon dog; (b) feral cat.

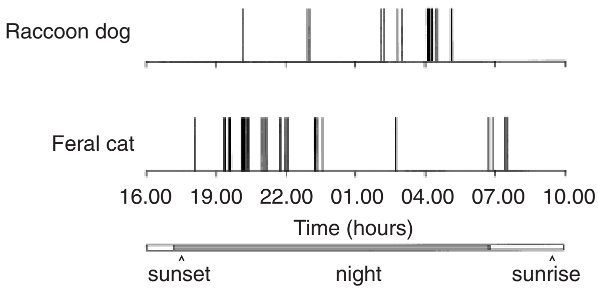

Fig. 3. Visiting patterns of wildlife revealed by the remote observation system. The time of the first photo in a series of photos of the animal's visit is shown. The raccoon dog visited the feeding site frequently between 02.00 hours and 05.00 hours (no. photographs = 20), while the feral cat was seen between 19.00 hours and 23.00 hours (no. photographs = 43).

two-tailed, $P = 0.00017$). The raccoon dog visited the feeding site frequently between 02.00 h and 05.00 h, whereas the feral cat was seen between 19.00 h and 23.00 h. We have too little information to draw a conclusion from the results now, although Kaneko *et al.* (1998) have reported that raccoon dogs are active throughout the night.

Performance of system

In the field experiment, animals were photographed every several seconds during their stay. Only 1.8% of the total photos (28 out of 1574) contained no animal images. Such photos were probably taken when grass moving or falling leaves in the background were detected, indicating that the monitoring software is reliable and sensitive enough to detect slight movements of objects effectively.

In the system verification experiment, the number of photos yielded was generally proportional to the length of the animal's stay on screen (Fig. 4a; $R^2 = 0.71$, $P < 0.01$, $n = 13$). The relatively poor goodness-of-fit is because of the animal's behavior, not because of the system. In some cases, animals appeared on a part of the screen but did not approach the feeding plate for a long time. Figure 4b shows the performance of the system when various parameter sets of monitoring software are applied to the scene of an animal's visit. The distribution of monitoring points on the screen and their sensitivity are essential for observing animals properly.

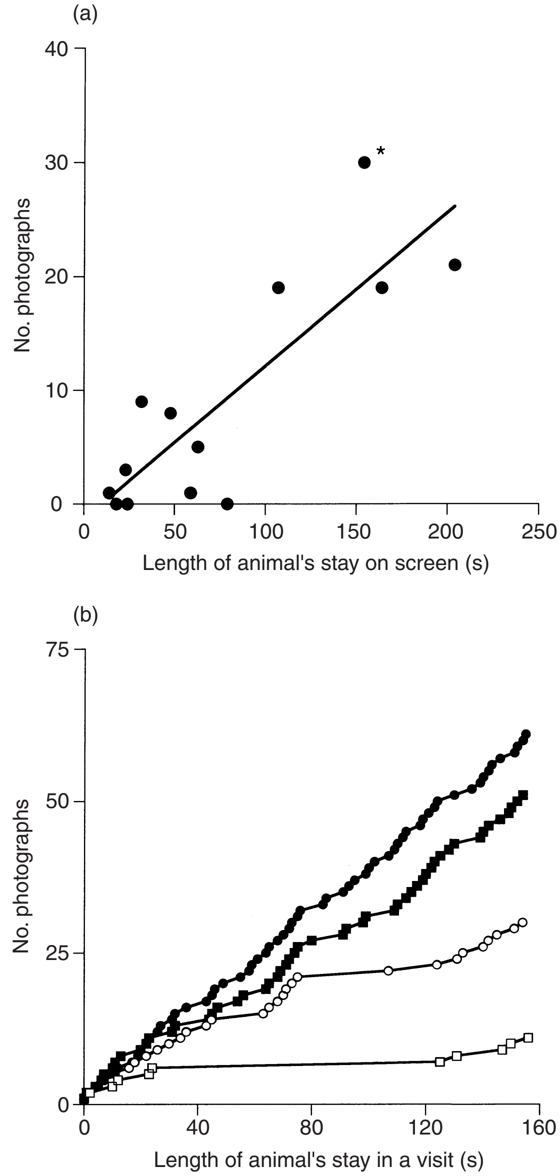

Fig. 4. Performance of the monitoring system. (a) Number of photos is generally proportional to the length of an animal's stay on screen. Low sensitivity; high density. *A scene of an animal's visit is used for (b) system performance under various parameter sets of the monitoring point: high sensitivity (value = 30); low sensitivity (value = 60); high density (clumped); low density (sparse). (●), High sensitivity, high density; (■), high sensitivity, low density; (○), low sensitivity, high density; (□), low sensitivity, low density.

Network traffic

Data rate of the video streaming–monitoring experiment was small, at 35–70 kilobits per second (kbps) and 100–300 kbps for USB and

FireWire PC cameras, respectively, depending on the changes between frames. Frame rate was low (3 fps) with the USB PC camera, but sufficiently high (7–14 fps) with the FireWire PC camera, depending on the network traffic. This indicates that the motion of the video on the recipient computer was choppy, but still useful, when the USB PC camera was used, whereas the FireWire PC camera gave better results. The file size of photos obtained was small (≈40 kbytes), irrespective of which PC camera was used, indicating that there are no time limits for observation due to limited media capacity. These results show that the video streaming–monitoring system we developed requires neither powerful devices nor best-network capacity. The only requirement is a broadband network, of which capacity is at least several hundred kilobits per second; for example, DSL (Digital Subscriber Line) or fiber-optic line, which are coming into widespread use.

Further notes on system requirements

A minimum system requirement for the QuickTime streaming server is an Apple PowerMac with PowerPC G3 366 MHz or faster CPU, MacOS 9.04 or higher, and QuickTime 4.12 or higher, depending on the quality and resolution of the streaming video. Any type of digital PC camera with either USB or FireWire (IEEE 1394) that is compatible with the Macintosh can be used. PC cameras with over 0.3 million pixels, which give an equivalent or better resolution than standard videotape recorders, need a broadband network, whereas lower resolution PC cameras are suitable with a narrower network capacity. The only requirement for the recipient system is a moderate PowerMac that can run MacOS 9.0 or higher and QuickTime 4.1 or higher. A fixed IP address is required for the recipient computer to achieve a unicast streaming, which allows video streams to be sent to the IP address of one recipient. Only one copy of the network data is sent, and only the recipient can view the broadcast. However, this is not a problem in most cases of wildlife studies.

Advantages over other monitoring methods

The remote observation method presented in this report has great potential for ecological research and wildlife conservation. Researchers have acquired a powerful tool for observing remote wildlife via the Internet. In comparison with other 'offline' monitoring methods, the present system has two great advantages: (i) it is computer- and network-oriented; and (ii) its real-time operation. The collected data are stored in the computer electronically, thus making it easy to compile and analyze it with a computer. Also, there are no limits to observation time due to media capacity. Time-consuming processes, such as developing films or investigating boring videotapes that contain only a few animals' visits over several hours, are no longer necessary. The biggest problem that probably arises in field applications is power supply. This can be solved partially by using a generator or high-capacity battery.

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