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DESIGN OF A DURABLE EVENT DETECTOR AND AUTOMATED VIDEO SURVEILLANCE UNIT

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Abstract.—An automated video monitoring and surveillance system was developed that is capable of operation in hostile environmental conditions with a minimum of maintenance. Covert deployment, rapid installation, and a 3-mo operating life without battery change are features of the system. It provides real-time continuous video filming of events of interest. The power requirements and finite tape length dictated that it only film for short bursts, whenever an event of interest occurred. A reliable event detector using combinations of geophones and Passive InfraRed sensors is described. Such a video system has many applications in ornithological research and covert surveillance where it is not possible to have a person on site continuously. A number of problems have been overcome which are of general concern in such applications.

DISEÑO DE UNA SISTEMA DE VIDEO AUTOMÁTICO PARA MONITOREO Y VIGILANCIA

Sinopsis.—Se desarrolló un sistema de video para monitoreo y vigilancia que es capaz de operar en condiciones ambientales hostiles con un mínimo de mantenimiento. Los atributos mayores del sistema lo son despliegue de covertura, instalación rápida y tres meses de operación sin cambio de batería. El sistema provee para la filmación de video continuo de eventos de interés. Los requisitos energéticos y el tamaño finito de la videocinta, hace necesario el que se firme cuando ocurran eventos de interés. Se describe entonces un detector confiable que utiliza una combinación de geófonos y sensores infrarojos pasivos. Este sistema de video tiene muchas aplicaciones para trabajos de investigación en donde se necesite vigilancia, pero que no es posible tener a una persona observando todo el tiempo en una localidad. Se resuelven una serie de problemas que son de preocupación general cuando se utiliza este tipo de sistema.

Video filming has been widely used as a tool in the monitoring of birds (e.g., Haftorn 1972, Tommeraas 1989, Ouchley et al. 1994, Smith 1994, Sykes et al. 1995, Franzeb and Hanula 1995). In most reported work electrical power for the equipment has been either conveniently available in nearby buildings or supplied by portable generators. However, there are many cases where neither source is practical, because the location is too remote or covert installation is required. In this paper we describe a video system capable of remote covert operation for up to 3 mo on limited battery power.

SYSTEM DESIGN

We developed a system to monitor nests with the aim of collecting film evidence of the taking of eggs by humans. In the United Kingdom birds are protected by law, and it is illegal to take eggs or deliberately disturb wild birds unless they are a pest species. For some rare or threatened species such disturbance is a major conservation problem (Bibby 1990, Etheridge et al. 1997). For the species concerned, we were looking for

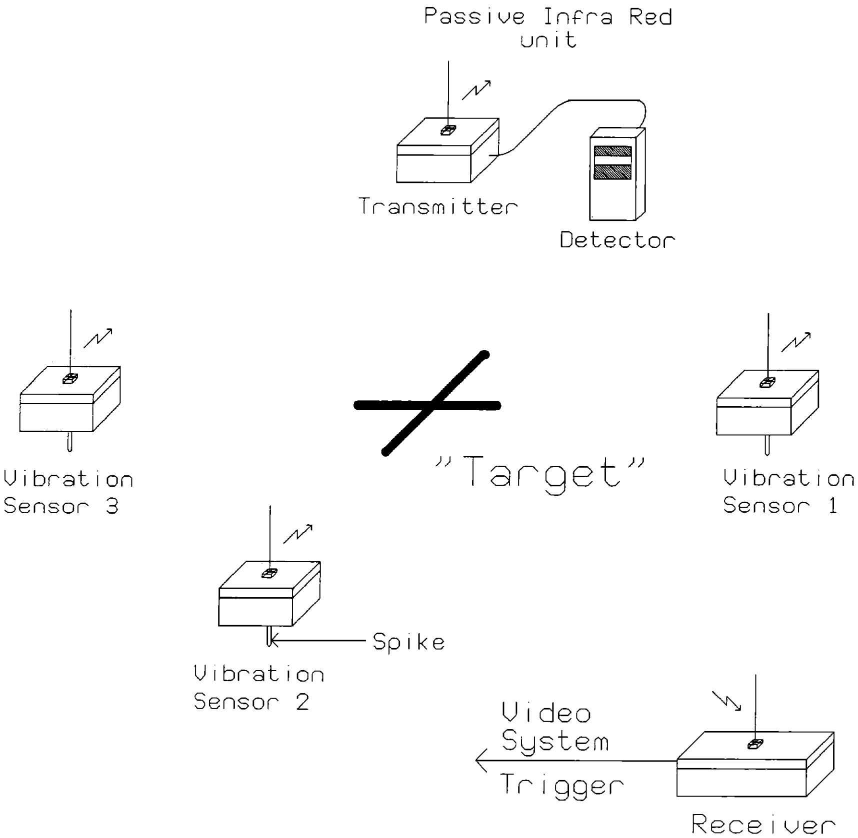

FIGURE 1. Block diagram of event detection system, showing an example of a possible configuration of sensors and radio receiver.

direct evidence for use in a criminal prosecution. Therefore, minimum maintenance and complete concealment were important considerations in design. Sites were usually inaccessible by vehicle, so regular battery replacement was not possible. The use of solar panels or wind generators was ruled out due to their conspicuousness. An approach was needed that eliminated the need for continuous power. One solution was to record only events of interest which, in turn, required a method of event detection. Upon detection, a trigger signal switched on the power supply to a video cassette recorder (VCR) and camera, which commenced recording for a specified time period.

Specific details of operating frequency and deployment of sensors and cameras have been withheld for reasons of operational security. The system design can be conveniently considered in two parts, the event detector and the video assembly.

Intruder/event detector.—The intruder/event detection system is composed of sensors and a receiver linked by short-range radio (Fig. 1). This radio link removes the need for cumbersome wire connections, and sensor locations can be adjusted to maximize chances of detection. The detector design incorporates features to reduce false detections and power consumption, allowing the use of smaller batteries and permitting longer operating life. The use of multiple sensors in conjunction with a receiver requiring several sensor inputs to trigger activation reduces the collection of redundant data, particularly when detection relies on more than one sensing method. It is important that the sensors be reliable within the constraints imposed by other design parameters. However, when small size and long operating life are important these requirements tend to work against the use of sophisticated sensor signal processing because of the power required.

Two types of sensor were developed, a vibration sensor and a Passive InfraRed (PIR) sensor. Each sensor transmits its status and unique identification code. A routine status check transmission is made every 6 min. Each sensor requires, on average, less than 200 μA and operates for a minimum of 3 mo from four AAA alkaline batteries.

In our application, events of interest involved human activity at nests. Footfalls, either human or animal, produce ground vibrations. Therefore we used a geophone (Western Geophysical SM-4/U-B 10 Hz 375 Ohm vertical) as a transducer to detect such vibration. A geophone is a moving coil device that generates a low-frequency (a few tens of Hertz) AC voltage when subjected to vibration. This is amplified and subject to detection by threshold (i.e., when the pulse amplitude exceeds a threshold level it is assumed that an 'event' has occurred). To aid discrimination of human footfalls from other sources of ground vibration the sensor had built-in geophone signal gating. To set off a radio transmission two shocks had to be detected, the second shock having to fall within a prescribed time following the first. The sensor is thus immune to single shocks and continuous vibration. For covert operation it has an advantage over the PIR sensors because it is buried, difficult to see, and can be installed quickly.

Sensor sensitivity is programmable to allow for different conditions. To aid coupling of vibration from the substrate to the transducer, a spike is securely fastened to the sensor box and driven into the substrate. In dry loose soil coupling of vibration energy is poor, and the sensor sensitivity must be set high. In damp peaty soils vibration travels well and coupling is good, requiring lower sensitivity.

The PIR sensor used a transmitter unit almost identical to that of the vibration sensor, interfaced to a commercial 'micropower' 5 μA PIR detection unit [Visonic SRN-2000C/PC-E]. The PIR sensor itself had adjustable tolerance to false detections. The number of separate detections required, within the space of approximately 1 min, for the PIR's output to trigger can be varied from one to five. The PIR sensor is a sensitive device with a detection range of 20 m or more over a wide field of view. This viewing angle can be tailored to a particular site by selecting the most appropriate fresnel lens.

It is more difficult to hide a PIR than a vibration sensor because it must 'see' the target area. Under sunny conditions, false detections can arise when sunlight is broken by moving vegetation or fast moving clouds.

The receiver picks up transmissions from the sensors and processes them. The receiver has no limit on the number of sensors. It can provide data on the status of each sensor and signal to commence filming. The user programmes the number of event detection transmissions required and the time window (T) within which they must be received to trigger filming. Each sensor has an inhibit-delay following transmission, the length of which is adjustable. This prevents transmission of an event detection signal for a time greater than T, so that a single sensor being continually activated cannot trigger filming. The requirement of signals from several sensors to trigger filming leads to a reduced rate of unwanted filming due to spurious detections by individual sensors.

The power consumption of the receiver is dominated by the Radio Frequency Receiver Module. By rapidly switching the module on (5% of the time) and off (95%) the power consumption of the receiver is reduced by >90%. Operation over a 3-mo period can be maintained with four AA Alkaline batteries, supplying 6 V at a rated capacity of 2.6 Ah. To ensure no event-detection transmissions were missed in the receiver's off period, the radio signal from a sensor carries no information for the first 120 ms of transmission. The receiver triggers the video system relay timer through a cable.

Video system.—The Video system consisted of a camera, cables, and a case containing the VCR, batteries, and timer (Fig. 2). Table 1 lists the major components of the video system. A Watec 801 CCD video camera with C-mount auto-iris lens (50 mm fl.4) was mounted in a custom-built housing. No commercial housing could be found that met both the waterproofing requirements and the need for small size so a custom housing was constructed. Silica gel pouches inside alleviated condensation. The VCR case was made of polypropylene and waterproof for 10 m immersion (Pelican Protector 1600). Three connectors in the case wall were used to connect to the camera, radio receiver, and external battery, for the VCR heaters, via cables. Video system power was provided by two 12 V sealed lead-acid batteries (15 Amp-hours and 4 Amp-hours capacity). A delay timer controlling integral relays connected the batteries to both VCR and camera upon triggering from the radio receiver.

A VCR for this application requires a number of features. It must put date and time on the picture. The VCR's internal clock must remain accurate for up to 3 mo without mains power. It should be able to begin/resume recording immediately upon power connection, and it should run from a battery. We used Mitsubishi HS-480E time lapse VHS VCRs, which satisfied the date/time and record-on-power-up criteria. With internal modifications the other two points were satisfied. The use of camcorders was rejected because they are large in comparison with small cameras, not as easy to conceal, and the viewing and replacing of tapes would disturb the camera position, which has to be carefully set.

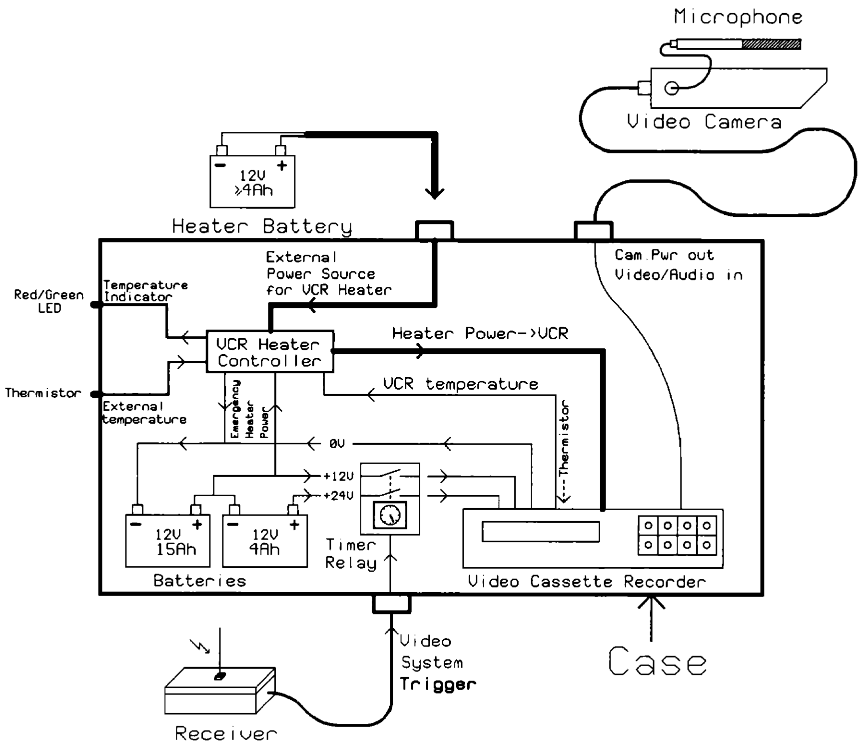

FIGURE 2. Diagram of the video system showing the configuration inside the VCR case, its inputs, and outputs.

TABLE 1. Key components of the video filming assembly.

Description	Make	Model	Size mm	Mass kg	Cost U.S.$
Video camera body	Watec	801	57 × 57 × 48	0.14	400[a]
50 mm camera lens	Computar	MCA5018APC	54 × 53 dia.	0.18	200[a]
Microphone	Pro-Sound	YU-36	280 × 22 dia.		60
VCR case	Pelican	1600	59 × 53 × 23	8.2	175
Time lapse VCR	Mitsubishi	HS-480E	424 × 379 × 99	7.5	2700[a,b]
Timer relay	Radio Spares	329-238			60
12 V 15 Ah battery	Yuasa	NP15-12	180 × 167 × 76	5.9	70
12 V 4 Ah battery	Yuasa	NP4-12	90 × 105 × 70	1.8	35

[a] These components have been superceded.
[b] The price of contemporary equivalent units is considerably lower at around $1500.

The trigger signal from the receiver activated the relay and powered the video system. Recording commenced for a preset period controlled by the relay timer. As long as activity was detected by the sensors the recording continued. The VCR tape had a duration of 3 h. Battery capacity was chosen accordingly. The current consumption of the video system when de-activated was 3 mA.

When deployed the VCR case was buried at a depth of up to 1 m, where the soil temperature was less variable than the ambient air temperature. During the first two seasons there were several occasions where the VCR was disabled shortly after the case was opened because the humidity sensor detected condensation from warm humid air entering the VCR. To correct this problem, all VCRs were equipped with an integral high-power resistor and fan that form an internal heating system for the VCR (delivering approximately 30 W). These components are positioned around the VCR head assembly. So the user can assess the temperature differential without opening the case, an external battery is connected via a connector in the case wall. If the user has forgotten to take a battery to site for this task the internal battery can be employed without opening the case; the connector is configured so that a modified cable connector "key" will connect the internal battery to the heater but, of course, this significantly reduces the power available for subsequent recording. Power is supplied to the VCR's internal heater and to a light-emitting diode (LED) mounted on the case lid, which shows the current status. When the outside temperature is greater by 3 C or more from the internal VCR temperature the LED is red. The case is only opened when the LED goes green, indicating equalized temperature. In the field this procedure took at most 8 min. Internal and external temperature detection is carried out by two thermistors, one mounted next to the VCR's internal humidity sensor, the other on the outside of the case. A circuit inside the case compares the two temperatures and controls the LED.

Standard VHS VCRs are large and require large waterproof housings, which could be difficult to hide. We looked for a more compact unit and found it in the Sony EVC500E Hi8 VCR. It required less power but needed substantial modification to meet our VCR requirements. A separate date/time stamp generator had to be used but did not require a larger case than for the Hi8 alone. Only one system has been built that operated satisfactorily. Unfortunately Sony has now discontinued sale of the EVC500E and the replacement has dimensions similar to our original VHS units.

PROBLEMS THAT WERE OVERCOME

This system was developed over three field seasons. Several problems had to be overcome and are described below.

Leakage.—Water entered unsealed VCR cases so we switched to lightweight sealed IP68 units. Cables in the initial design entered the case through grommets that proved to be an inadequate seal for burial. The new design used IP68-rated bulkhead connectors instead.

Geophone sensitivity setting.—In the main trials we used only ground vibration sensors. The 'gating' within the geophone coupled with the multiple detection strategy eliminated most of the false video triggers. However, it was difficult to set the geophone sensitivity levels and required experimentation near the sites to get the correct balance between detection range (the more sensitive the better) and false detections originating from the effects of wind (the less sensitive the better).

SYSTEM PERFORMANCE

Three systems were deployed on a total of five occasions over 1997, a cumulative deployment time of 3700 h. We tested that the systems were still operational by walking up to the sensors. On average the video system recorded in response to triggering for 72% of this time (range 50–89% per site, SD = 19%) rising to 77% when operator error is ignored. Tape length was the primary limiting factor, running out due to repeated false activation during windy conditions. At each site visit following installation, the system was tested by walking toward the nest. It never failed to detect the tester.

DISCUSSION

Reliable detection and filming is of particular importance where a single event is of interest and events occur only rarely. In general the video systems demonstrated high reliability in terms of triggering and filming in response to triggers from the event detection system. Previous problems of VCRs disabling themselves due to condensation have been eliminated with the incorporation of the internal heater arrangements. We did suffer two instances of ingress of water into equipment housings, but these were resolved. Burial of equipment did bring an attendant problem of enclosure and connector seals being compromised by soil and plant matter. Ensuring this did not happen required vigilance on the part of staff deploying and attending the systems.

The vibration sensors did suffer from over-sensitivity to ground vibration arising from wind energy being transmitted to the roots of surrounding vegetation. The sensitivity of the sensors could not be reduced without compromising their effectiveness in detecting footfalls. Using five or more vibration sensors at each site, with the receiver requiring signals from at least three sensors to trigger the video system, did cut down false triggering. The situation was further improved when PIR sensors were added. We are developing geophone units that can adjust their sensitivity to the prevailing conditions. This will simplify installation and reduce the number of false triggers.

Vibration sensors, if buried, are hidden from the eye and have an obvious advantage for covert deployment. They are suitable for detecting animals and humans, rather than birds. PIR detectors provide more reliable detection of fauna and their use is preferred. Reliability is further increased with PIR detectors employing multiple pulse counts. 'Dual Technology' sensors, incorporating both PIR and microwave doppler radar to reduce false activations, require too much power for battery-powered applications. PIRs detect moving body heat and can be used to detect, for example, arrival and departure of adult birds at the nest, incidents of nest predation, and general nest activity. Suitable sensor positioning allows detection of birds from small passerines to large raptors. Event detection systems can also be used to trigger apparatus other than video. Examples include still cameras (Franzeb and Hanula 1995) and mass measurements (M. Douglas, pers. comm.). Employing multiple sensors in conjunction with a receiver with inputs from several sensors before activation can reduce time wasted in processing recorded data. This is particularly true for video systems where several hours may be required to analyze taped sequences. It also reduces energy requirements, easing transport needs and reducing costs, which may be important in long-term studies.

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